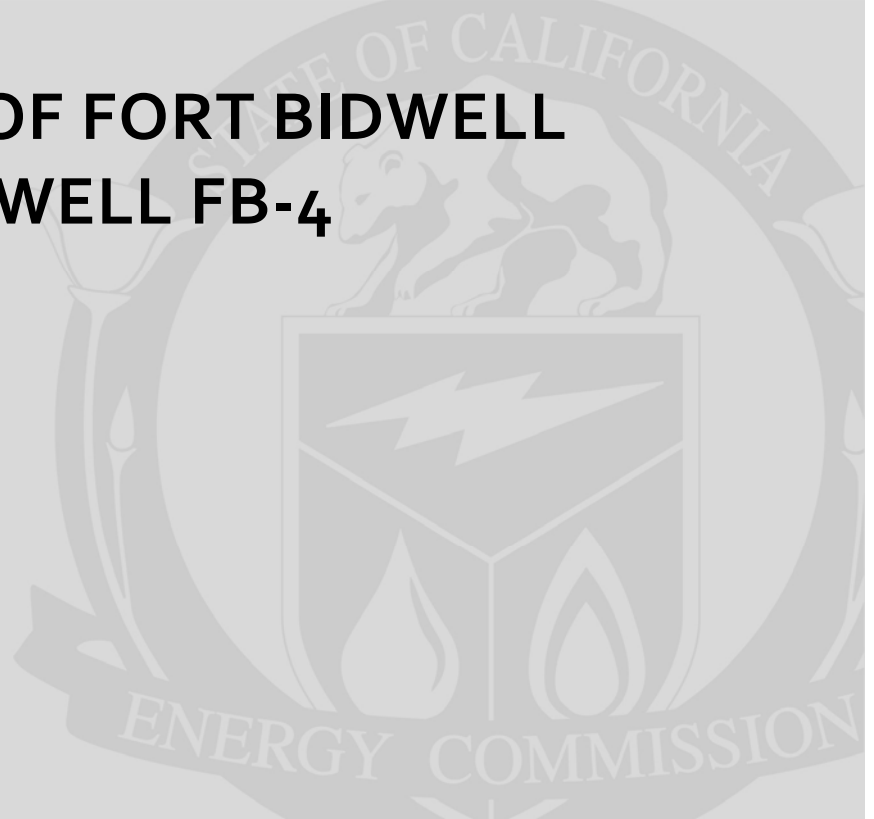
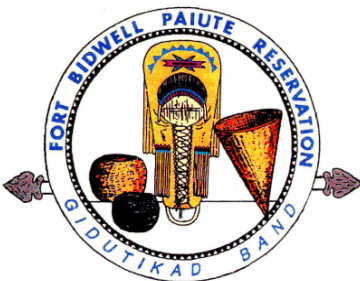


Public Interest Energy Research (PIER) Program FINAL PROJECT REPORT

ASSESSMENT OF FORT BIDWELL GEOTHERMAL WELL FB-4



Prepared for: California Energy Commission
Prepared by: Fort Bidwell Indian Community Council



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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

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- Renewable Energy Technologies
- Transportation

Assessment of Fort Bidwell Geothermal Well FB-4 is the final report for Fort Bidwell Reservation Geothermal Well Test project, Grant Number GEO-07-004, conducted by the Fort Bidwell Indian Community Council. The information from this project contributes to PIER's Renewable Energy Technologies Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

Abstract

The Surprise Valley in the very northeastern corner of California's Modoc County has various hot springs that indicate the possible existence of geothermal systems that may have potential for either direct use or commercial power generation. The FB-4 well was drilled in the Fort Bidwell Indian Reservation in 2007 as an exploration of the underlying resource that began in the 1980s. Lack of funding caused the well to be left untested and, with an open hole in the lower, potentially productive section.

The present study was funded by the Geothermal Resources Development Account. Researchers returned to Well FB-4 to take measurements to complete the planned assessment of the geothermal resource that the earlier drilling had penetrated. These measurements could not be made because the open hole was found to be obstructed above the likely production formation. However, the data obtained from FB-4 have been analyzed, and the result was consistent with the originally hypothesized model of a lower-temperature geothermal reservoir with an estimated minimum anticipated reservoir temperature of 143° C (289° F). The study provides recommendations and cost estimates for the activities needed to complete the originally planned assessment of the well and reservoir. It also provides documentation of all underlying data for the well, which is required for any further assessment of the well and resource.

Keywords: Geothermal energy, exploration, drill cuttings analysis, well bridging, hydrothermal system model, conceptual models, Surprise Valley

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Executive Summary

Introduction

Based on the presence of local hot springs, it has been known for many years that a potential geothermal resource underlies Fort Bidwell and the Fort Bidwell Indian Reservation in northeast Modoc County, California. The most recent effort to explore this resource occurred in 2007 when the FB-4 well was drilled. Due to lack of funds, the well was left untested and with an open hole in the potentially productive part of the reservoir.

Purpose

Using Geothermal Resources Development Account funds, this project returned to the well and attempted to complete the testing and evaluation planned in 2007. Physical changes in the well bore since the drilling was completed precluded full well testing in this project. However, preliminary work as described below was completed so that interested parties would know the next steps to achieve a full resource assessment.

Objectives

The broad objectives of the project were to:

- Make temperature and pressure measurements in the well.
- Flowtest, collect representative samples for chemical analysis, and run a pressure build-up test.
- Analyze and integrate these results into an assessment of the resource, including potential for power generation or direct use.

Conclusions and Recommendations

It was determined that the well has an obstruction that precluded carrying out the planned measurements and assessment. This project analyzed all data gathered for the well and tested the results against the proposed conceptual model of the hydrothermal system that was used to target the well. The project also resulted in full documentation of this data, which is required for any subsequent evaluation of investment in assessing the resource, and therefore, valuable for any further exploration.

All data obtained during drilling is consistent with the proposed model, and the previous estimate of a small geothermal system with a minimum temperature of about 143°C (289°F) remains valid.

It is recommended returning to the well with a drilling rig to clean out the obstruction, rig test the well, and then, if the test results are supportive, run a protective slotted liner into the hole. After this is complete, the authors recommend that the well achieve thermal equilibrium, then temperature and pressure surveys be run in it. Finally, complete the testing program as originally planned.

If the geothermal resource at Fort Bidwell is found to have potential for either commercial power generation or direct use, it may provide a variety of benefits to California. These include reduction of greenhouse gas emissions, reduction of energy imports, and the development of jobs and infrastructure.

1.0 Introduction

The FB-4 well was drilled on the Fort Bidwell Indian Reservation in September and October of 2007 using a combination of funds provided by the Fort Bidwell Indian Community, the California Energy Commission, and the US Department of Energy Geothermal Technology Program (LaFleur, 2007a, 2007b).

The well was left untested and with an open hole below the 9 5/8" casing shoe at 2785 ft depth due to lack of funding. The purpose of this project was to return to the well, assess its down-hole temperature state, and then flowtest it in order to provide the basis for an assessment of the hydrothermal resource targeted.

The well was found to be obstructed. Since there were insufficient funds available to clean it out and continue with the flowtest evaluation no further field work was done. This report presents:

- an evaluation of the data available.
- an update of the conceptual model for the reservoir.
- recommended next steps & estimated costs.
- observations about the potential size of the resource.
- data for the resource previously available only in unpublished form.

The materials presented herein are required in order for potentially interested parties or organizations to be able to make an assessment of the tradeoff between benefits and costs of additional investment directed at evaluating the potential of the underlying geothermal resource.

2.0 Well FB-4 Test and Other Data

2.1. Basic Well Information

Key well and resource data collected during this project is presented in Appendix A. This includes:

- A location topographic map of the four Fort Bidwell geothermal wells, FB-1, -2, -3 & -4.
- Well FB-4 schematic and master valve description.
- Well FB-4 activity reports.
- Well FB-4 Cuttings Analysis.
- Well FB-3 activity report on September 3, 2009, temperature & spinner survey on May 18, 1987 and well schematic.
- Well FB-2 Schematic.
- Well FB-1 Schematic.

Additional information acquired during the drilling of the well is contained in the daily drilling reports and the geologic log, submitted as Attachments 1 and 3 by LaFleur (2007a, b).

2.2. Test Data Obtained

During the course of this project, only the first step in Task 2.2 (Well Testing) could be physically accomplished - run wireline pressure and temperature surveys. This occurred because the first survey attempt on September 3, 2009 encountered a bridge or obstruction at 3030 ft below ground level (GL), which is 3059 ft below the kelly bushing (KB).¹ The well was investigated a second time on February 24, 2010 using wireline tools that allowed for the confirmation of a firm obstruction at a depth of 3036 ft GL or 3065 ft KB. The obstruction has not moved - the six-foot difference between this and the previous depths is due to different wireline operators. The more recent survey depth measurement is used in the remainder of this report.

This obstruction occurs only 280 ft below the casing shoe at 2785 ft KB, and 1605 ft above the well total depth (TD.) This is depicted schematically in Figure 1.

¹ Kelly Bushing depth refers to the standard reference point from which depth measurements are made in a drilling operation. The kelly bushing is a specialized part of the drilling equipment that occurs on the drilling rig floor. Different drilling rigs will have kelly bushings at different elevations above ground level.

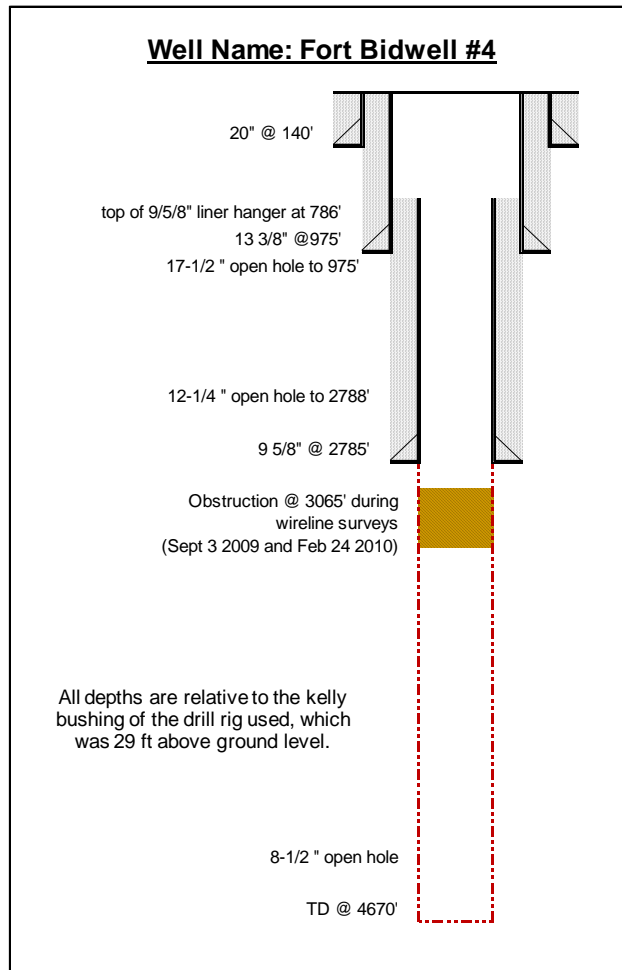


Figure 1 – Well FB-4 Simplified Schematic (not to scale)

Pressure and temperature gradient surveys were run down to the obstruction on September 3, 2009. Figure 2 presents the results:

- The liquid level was encountered at 300 ft GL; and
- Measured temperatures have a “conductive” gradient down to about 2000 ft GL, below which it is approximately constant.

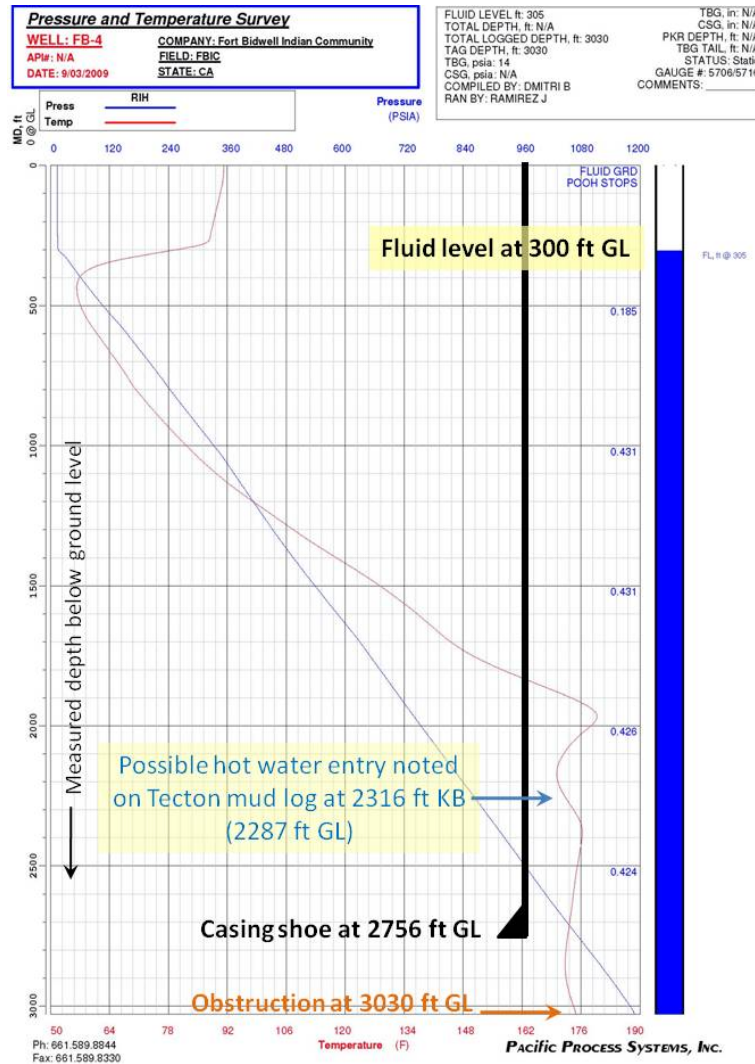


Figure 2 – Results of September 3, 2009, Pressure and Temperature Gradient Survey in FB-4

This figure also shows the small interval of the well which is potentially open to the reservoir in the open hole above the obstruction. Three observations can be made about the temperature and pressure data obtained:

- The temperatures of approximately 175° F below 2000 ft GL should not be taken to be representative of conditions encountered by the well in the hydrothermal system below the obstruction. They, can however, be taken as a stabilized measure of conditions above the obstruction.
- The pressure in the open-hole section of the well above the obstruction can probably be taken as representative of the hydrothermal system encountered by the well both above and below the obstruction. This is because pressures in the system would be expected to equilibrate more rapidly than the development of the bridge, so would likely have been in equilibrium by the time the bridge formed.

- The pressure in FB-4 just below the casing shoe is in approximate pressure equilibrium with the pressure in FB-3 at the same datum level, indicating that they are likely to be connected to the same hydrothermal system. This observation is based on an inferred ground level elevation of 4745 ft ASL and slightly positive shut-in pressure for FB-3 (for elevation, see the topographic location map on the 1st page of Appendix A, and for wellhead pressure, see Lawrence, 1985, p. 3).

2.3. Cuttings Analysis

Following the drilling of FB-4 a complete set of cuttings from the well were sent to the Energy & Geoscience Institute at the University of Utah. Clay Jones and Joseph Moore from this institute have provided a report describing their petrographic and X-ray diffraction analyses. This is provided beginning on page 8 of Appendix A.

Figure 3 presents the well's lithologic column from this report, along with key drilling events and the location of the top of the obstruction. This figure shows that the top of the obstruction is at the top of a major rhyodacite flow. The tops of such flow units are commonly fractured or brecciated, which is consistent with this being the top of the collapsed hole.

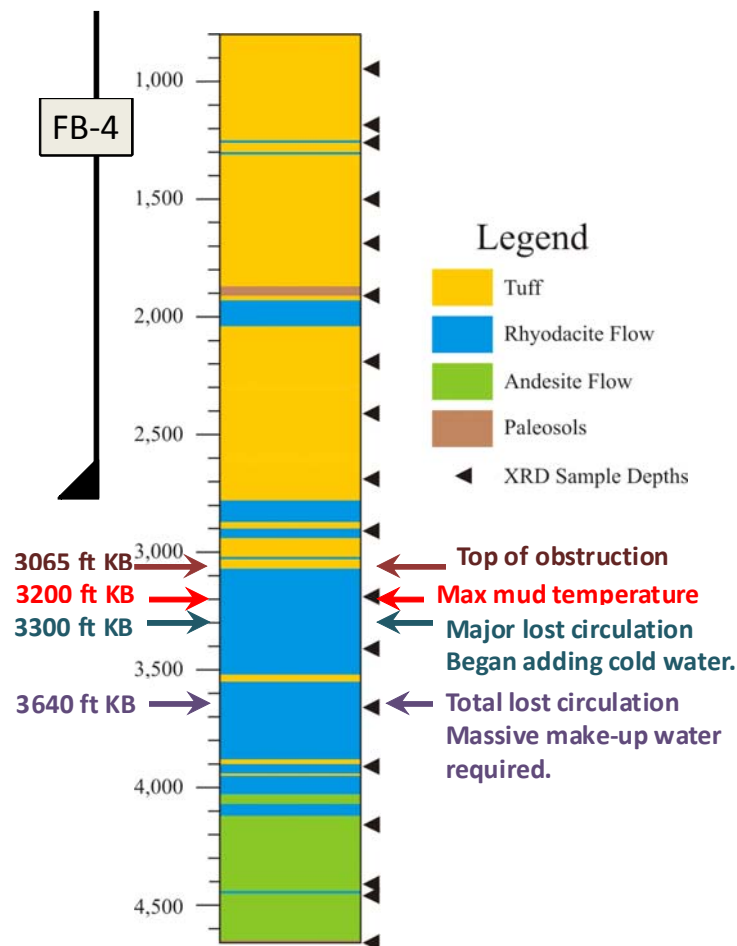


Figure 3 – FB-4 Lithologic Column and Key Drilling Events

Figure 3 also shows that the major drilling events indicative of fracturing or hot fluid entry occur below the top of the obstruction:

- i. The maximum mud-out temperature at 3200 ft KB
- ii. A major lost circulation zone at 3300 ft KB, after which cold water was added to the mud system to make-up for lost drilling fluids
- iii. A total lost circulation zone at 3640 ft KB, with even more make-up water needed to be added at this depth and regularly for the rest of the well

2.4. Temperature Implications

The maximum mud-out temperature “kick” at 3200 ft KB as seen on the computer real-time display of drilling parameters (Pason chart) is presented in Figure 4, which is taken from the FB-4 drilling final report (LaFleur, 2007a & b, pg. 5.) This increased temperature of the return drilling fluid was strongest in the interval of about 3,080 to 3,260 ft KB depth. The highest mud-out temperature recorded was 152° F at the depth of 3,200 ft KB. At 3,300 ft depth, the well experienced significant mud loss, so 200 barrels of make-up water and 60 bags of lost circulation material (LCM) were added. The mud temperature began to build again but total lost circulation and massive mud loss occurred when the hole was at a depth of 3,640. After this depth mud losses required the regular addition of cool water to the mud system while making up lost mud volume.

Thus, the only significant hot water entry able to be seen during drilling was the temperature “kick” at 3200 ft KB. The lost circulation events at 3300 and 3640 ft KB may also be strong potential producers of hot water. However their thermal signature was masked by the addition of make-up water. There may have been additional zones of potential flow below 3640 ft – if so, they were masked by the continued addition of cool make-up water and lost circulation materials.

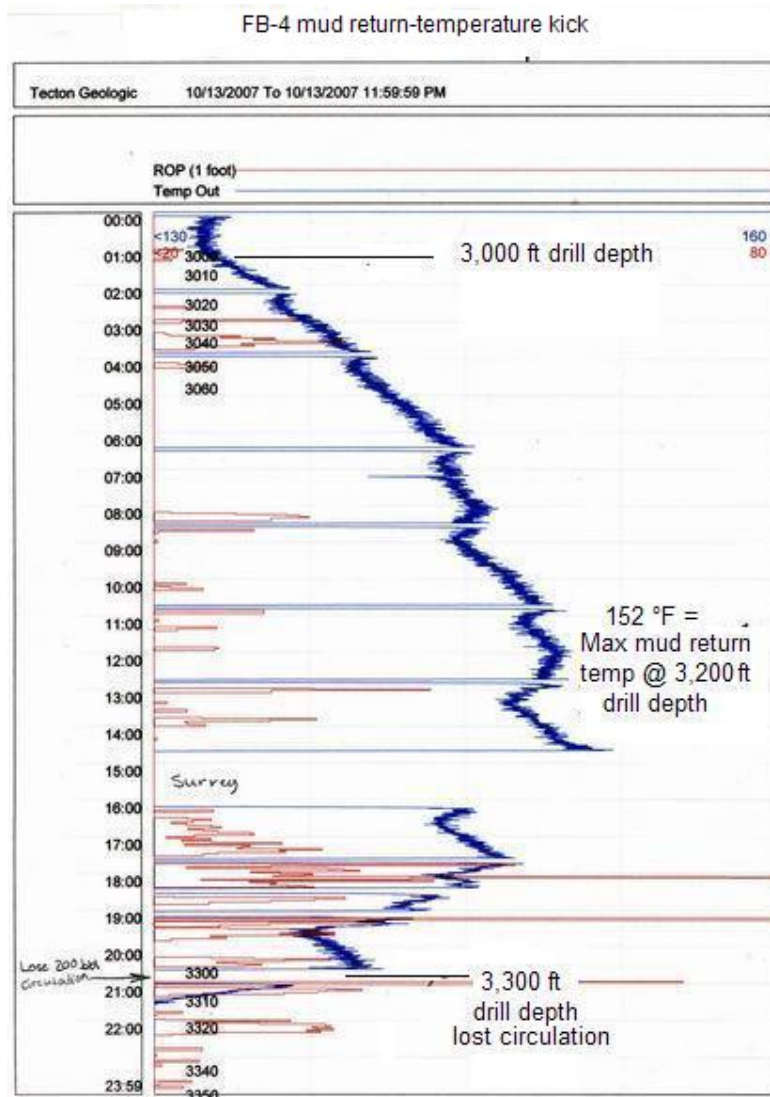


Figure 4 – FB-4 Mud Return-Temperature Kick

The petrographic and x-ray diffraction results provided by Jones and Moore provide some important insight regarding temperature of the hydrothermal system encountered in the well. No evidence for massive rock alteration or secondary mineralization was found, as would be the case for large high-temperature hydrothermal systems. Instead, they concluded that, “The persistence of smectite throughout the rock sequence suggests that temperatures during hydrothermal alteration have not exceeded approximately 180°C (356°F). At higher temperatures, interlayered illite-smectite would be anticipated. No interlayered clays were found.”

2.5. Wellhead Testing Equipment

Following the drilling of FB-4 in 2007 the wellhead was left with a 12” master valve on top of the casing head. No additional equipment was installed due to lack of funds. This left the top

of the master valve open to the atmosphere and unprotected, which is not recommended. Additionally, whenever the wireline survey operator came to the well special arrangements had to be made, as they would not normally carry the equipment to attach to a 12" flange.

During the course of this project a 12" top flange with a 3" ball valve and plug were installed on top of the master valve (see the March 12, 2010 well activity report on page 3 of Appendix A.) The top of the master valve is now protected, and well surveying and other evaluation work can be carried out without having to make special arrangements for attaching equipment.

2.6. Why Is the Well Bridged?

The cause of bridging is unexplained. However, a reasonable hypothesis is that the rhyodacite flow body which was encountered just above 3100 ft KB is brecciated, and caved in, causing the obstruction.

The occurrence of this obstruction and the need to return to the well a second time with a rig is likely a direct consequence of the funding limitations that applied when the well was drilled. In the normal course of drilling and testing a well, a short period of testing would be done with the drilling rig still over the well. If the well was assessed to be sufficiently productive, or worth protecting from an open-hole cave-in, a protective slotted liner would be run to TD. Even if no protective liner were run, the well would be left filled with host aquifer water.

It is possible that the well would have bridged during the originally planned rig test. If this had occurred, the rig would have been available to clean it out and then stabilize the hole. It is also possible that the obstruction resulted from interaction between the fresh water and formations exposed in the open hole. In either case, had there been sufficient funds to test and complete the well as originally planned, the well would most likely not have been left with an obstruction.

This sequence of operations was contained in the Work Statement for the Energy Commission project to drill FB-4 (Barker, 2005b.) This sequence of operations could not be completed because the costs of the total planned program would have exceeded the available funding. Instead, the drilling was stopped at a TD of 4670 ft KB and the drilling mud in the well was displaced with fresh surface water before laying down the drill pipe. This was done with the idea that it was better to leave fresh water in the well than potentially damaging drilling mud (Hamblin, 2010).

A review of the well history indicates no evidence of unstable hole, so one would not have anticipated that the well would necessarily be subject to unstable hole or the occurrence of obstructions.

Well FB-3 has had open hole below 286 ft GL since it was drilled in 1985 (see schematic on page 16 of Appendix A). The well was flowed for a short period in September 2009 and showed no obvious reduction in rate from the testing done in October 2004 (see September 3, 2009 Well Activity Report, page 15 of Appendix A). This would suggest that no obstructions to flow have developed in it, and thus that the formations encountered by FB-4 would also not be expected to experience obstructions. However, this explanation is less compelling when FB-3 is

juxtaposed against the FB-4 state and formations, as is done in Figure 5. This figure also shows the FB-3 fluid entry interval of 2150 to 2400 ft GL identified during a flowing spinner survey in the well on May 18, 1987 (see Appendix A, page 16).

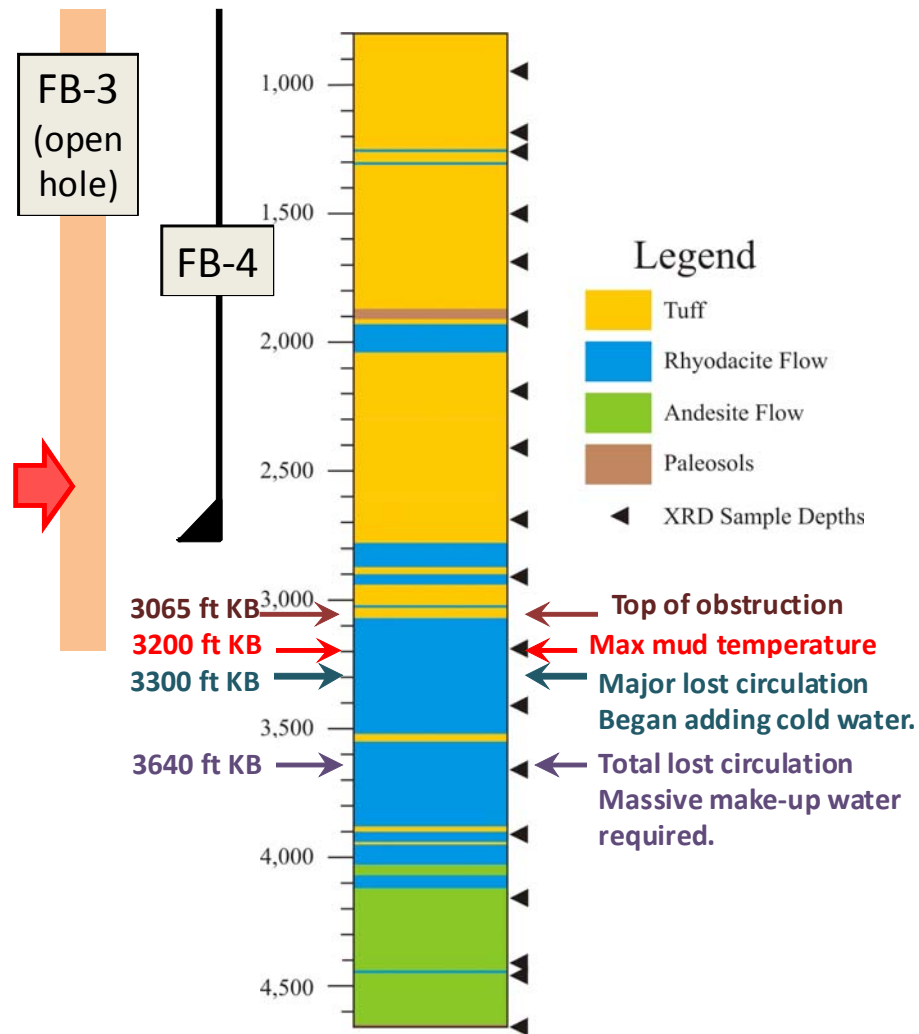


Figure 5 – FB-4 Lithologic Column and Key Drilling Events With Overlay of FB-3 Open Hole

The distance between the two wells is about 0.5 miles, so it is reasonable to hypothesize that they encountered similar formations and at similar depths. If correct, then the experience with FB-3 is less germane to that with FB-4 because:

- The failed portion in FB-4 is below the productive part of FB-3.
- The productive part of FB-3 has been cased-off and protected in FB-4.

2.7. Modification of the Test Plan

Only the first step of the test plan in the project Work Statement could be physically accomplished - run wireline pressure and temperature surveys. Appendix B contains the Communications and Emergency Contingency Plans that were in place during the wireline operations.

All of the remaining steps were precluded because of the obstruction encountered. An unsuccessful attempt was made to locate a contractor who could clean-out and test the well within the project budget.

This report presents all of the data acquired during the project, along with observations and interpretation. Additionally, new interpretation and observations relating to data obtained during the drilling of the well are included, as funding limitations prevented a full reporting and evaluation of these data at that time.

The project status is that the obstruction in the well has prevented the development of a reliable estimate of the well and resource's commercial potential.

3.0 Update of the Working Geologic Model

3.1. Introduction

During the drilling of FB-4 evidence of hot water inflow and good permeability was recorded. Reliable measurement of these parameters could not be accomplished during drilling and was necessarily postponed awaiting additional funding. The delay in returning to the well has allowed the hole to stand open without a protective liner and some caving-in has occurred, creating an obstruction in the well at 3,059 ft KB. This has prevented an assessment of the well's potential. Information obtained during drilling and from the temperature profile recorded in September 2009 allows for some conclusions to be made and provide a basis for next step recommendations.

Most significantly (so far) is that an impressive zone of hydrothermal inflow and high permeability, as evidenced by drill mud temperatures and losses, was encountered in a zone roughly between 3,000 and 3,600 ft depth.

The information that was gained during the drilling of FB-4 and the well temperature profile data recorded in the upper 65% of the well above the blockage, support the original working model (LaFleur, 2005). Although alternative conceptual models for the configuration of the Fort Bidwell hydrothermal system remain potentially valid, the original concept put forth in the grant applications was basically upheld by the drilling and data acquired to-date. Data additions to the original model, a modification of the original model, and a modestly different alternative model are discussed below.

Until the blockage is cleared and the hole is logged, these models remain speculative. Comprehensive reevaluation of the working model is not possible without the critical equilibrated temperature information from the bottom part of the hole, as well as flowtest results.

3.2. Information Gained While Drilling

Tecton Geologic provided on-site mud logging services during the drilling of FB-4. The data collected by Tecton was reported as a geologic log (Attachment 3 of LaFleur, 2007a & b), and included:

- lithologic descriptions of the drill cuttings.
- noted secondary minerals.
- in- & out- drill mud temperatures.
- notes on mud loss.
- drilling parameters such as weight on bit & penetration rates.

The data and information provided in the daily drilling reports (Attachment 1 of LaFleur, 2007a & b) and on the geologic log allow some conclusions to be drawn. One such conclusion is that we will not know what we really have in the well until it can be cleared, properly logged and

flow-tested. Another conclusion is that at least one significant hot water inflow was encountered at about 3,200 ft depth that is definitely worthy of future evaluation. Due to mud losses and the recurring addition of cold make-up water below that depth, it was not possible to discern if deeper hydrothermal entries were encountered.

The conclusions from petrographic & x-ray diffraction, and the temperature measurements obtained to-date in FB-4 are consistent with the lower-temperature geothermal reservoir forecasts included in the pre-drill project description (LaFleur, 2005). The figure of 143° C (289° F) was used in previous reports as the best estimate of minimum anticipated reservoir temperature. That figure was selected as most appropriate from the various geothermometry calculations performed on analyses of water from the FB-3 hot artesian well (LaFleur, 2005, page 20). Based on the FB-3 well geothermometry and the absence of significant rock alteration or hydrothermal mineral deposition at the surface, the current best estimate is that the Fort Bidwell resource appears to be relatively small and low temperature by geothermal standards. However, the current best guess of 289°F for the reservoir temperature is high enough to potentially be able to support geothermal energy production. For example, in 2009 the U.S. Department of Energy solicited proposal to demonstrate the technical and economic feasibility of geothermal energy production using off-the-shelf technology from low temperature resources in the range 150 to 300°C (USDOE, 2009).

3.3. Conceptual Models of the Hydrothermal System

Although complete results of FB-4 are still to be determined, it can be concluded that the drilling FB-4 to the west of FB-3 was an appropriate choice. The hot water entries recognized in FB-4 indicate that the 210° F outflow zone seen at 2,330 ft depth in FB-3 is coming from higher up in the Warner Range block west of Fort Bidwell. The following presents three simplistic model cross sections consistent with the data available:

- The original Fort Bidwell geothermal geohydrological model (LaFleur, 2005).
- A modification of the original model.
- An alternative model reflecting a different possible upflow fault than the one targeted.

3.3.1. Original Model

Figure 6 presents the original model proposed (Figure 15 of LaFleur, 2005) with the addition of the obstruction location at 3036 ft GL (1982 ft ASL).

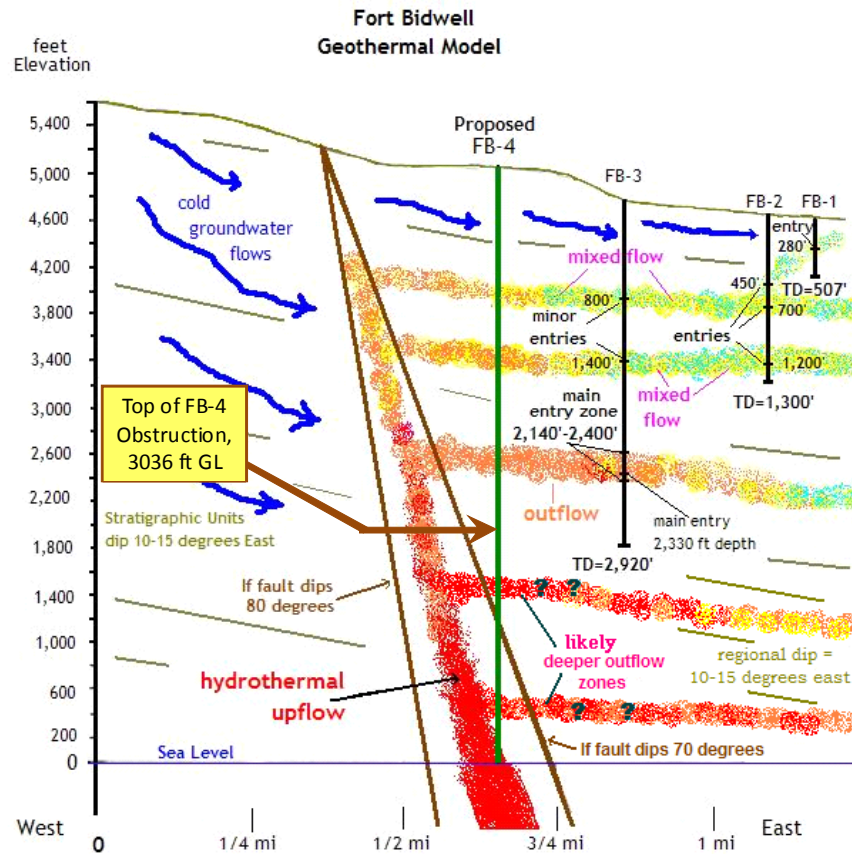


Figure 6 – Schematic of Original Model With FB-4 Obstruction Added

This model showed a possible range of 70°-80° dip on the target fault (Figure 8 of LaFleur, 2005). This dip and position was estimated from field observations and based on the considerations discussed in Appendix C. There are three ways in which this model might match the FB-4 data obtained so far.

1. It is possible that FB-4 did encounter the target fault at a drill depth of about 3,300 ft where major mud loss occurred coincident with a significant rise in mud-out temperature. If this is the case, it may indicate that the target fault may dip slightly less than 70°. A 66° dipping fault plane was added to the original model to illustrate that small difference.
2. A huge mud loss occurred when the bottom of the hole was at 3,640 ft KB. This apparent loss zone could be the target fault, giving it almost exactly the estimated 70° dip, or it could be that it was just coincident recurring mud loss actually taking place at the 3,300 ft loss zone.
3. Also reflected in the original model is the real possibility that the FB-4 Well did not penetrate deep enough to reach the target fault. Note on the cross section that if the fault is dipping at 80° (or greater), the real upflow zone may occur below the present bottom hole depth. Temperature gradient measurements from the lower portion of the

hole (below the bridge) will be required to evaluate this possibility. Without this data, the possibility of deeper upflow faulting cannot be removed from the original model with confidence.

While this model is still considered the most likely configuration, two additional possible models are described below.

3.3.2. Original Model With Simple Modification

Figure 7 presents a modified version of the original geohydrology model which illustrates how the hot water entries observed in all four of the Fort Bidwell wells may relate.

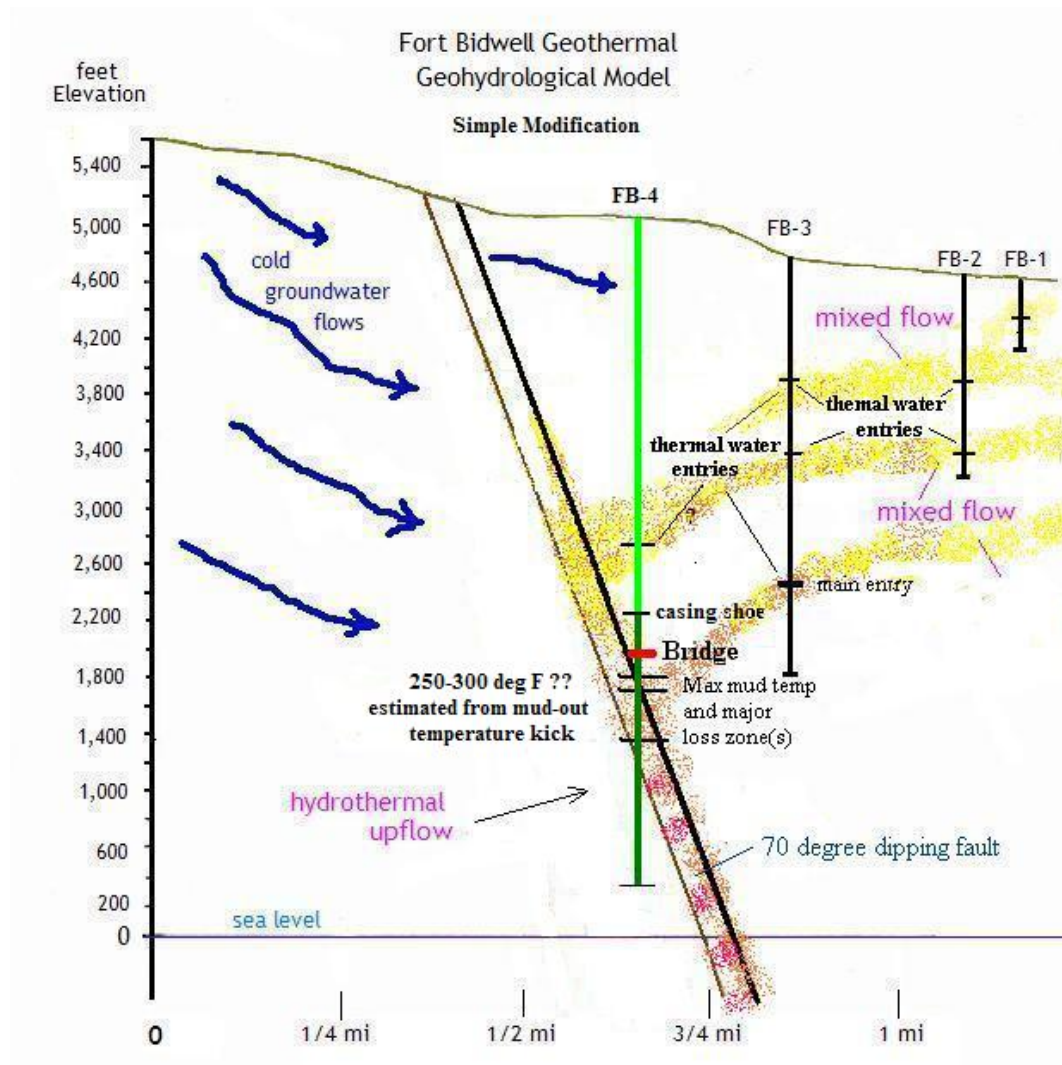


Figure 7 – Schematic of Original Model With Simple Modification

This simplified version is compatible with the data collected to date in the FB-4 Well. It suggests that the primary upflow fault, dipping at 70°, was encountered as was originally targeted. Also implied is that the upflow is of moderate temperature as indicated by the estimates from mud-out temperature, the absence of high-temperature secondary mineralization, and the geothermometry from the FB-3 water samples.

3.3.3. Alternative Model With Upflow Fault Farther West

It is entirely possible that the FB-4 Well did not hit the upflow fault, but rather it encountered outflow from an upflow fault farther uphill to the west. This is depicted in Figure 8.

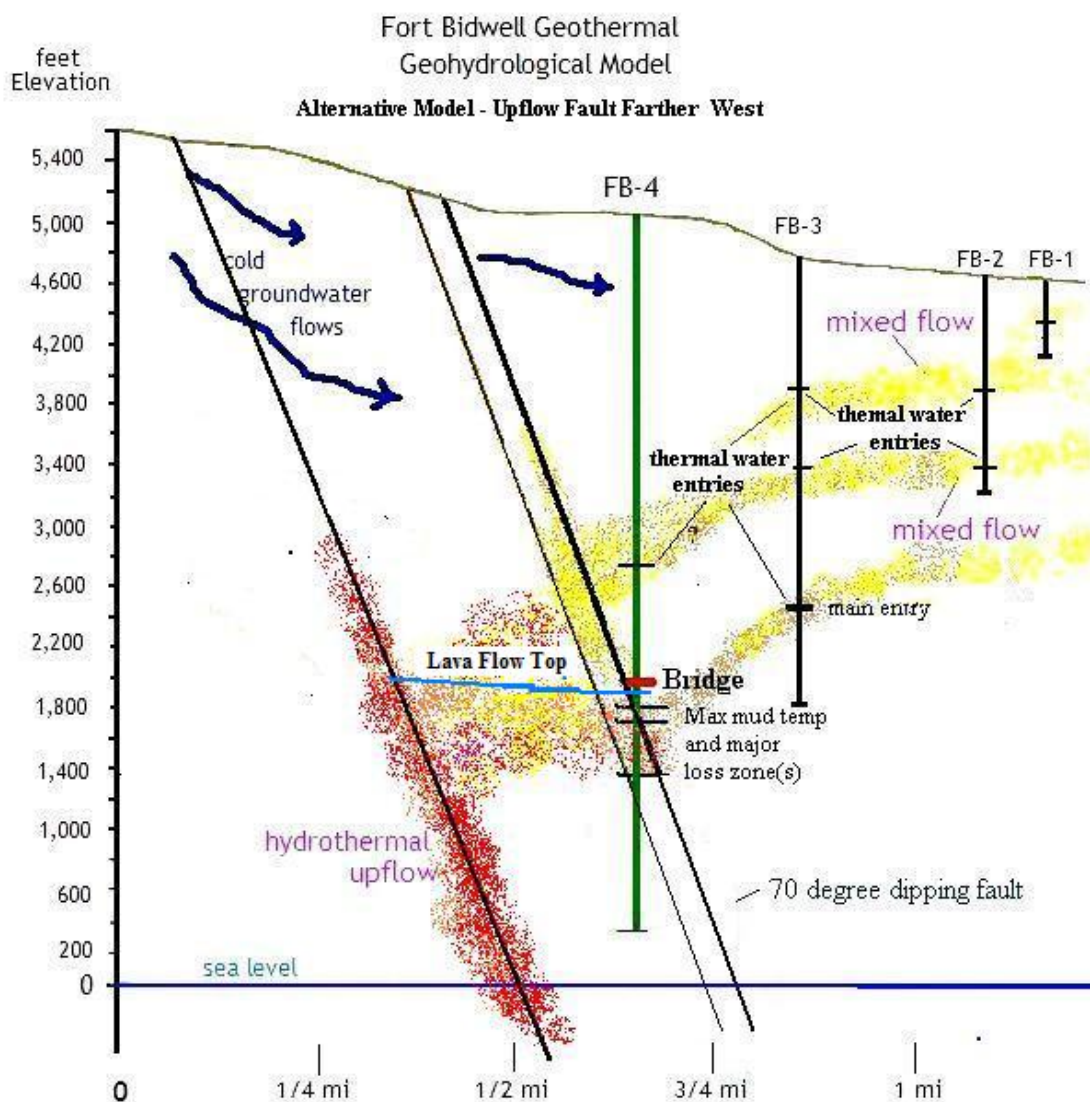


Figure 8 – Schematic of Alternative Model With Upflow Fault Farther West

As shown in Figure C-1, large sub-parallel faulting occurs west of the FB-4 targeted fault. If the upflow is actually occurring on one of these faults, outflow would be eastward toward FB-4 and Fort Bidwell. Outflow would take place within a fracture permeability aquifer, as is often afforded by hard, brittle lava flows.

According to the FB-4 Lithologic Column and Key Drilling Events (Figure 3), the mud temperature kick and mud loss zone are nicely coincident with the top of a thick rhyodacite lava flow described as being "... glassy to fine-grained and may be flow-banded, vesicular, auto-brecciated and/or devitrified" (Appendix A, Rhyodacite Flows description, pg 10). Auto-brecciation typically occurs at the top and base of a lava flow. This alternative model is

essentially the condition that was encountered in the FB- 3 well which penetrated an outflow zone at 2,330 ft depth, about 600 feet above the final bottom-hole depth. It was the recognition of this outflow condition in FB-3 that prompted the siting of FB-4 to the west upstream of the regional hydrology.

3.3.4. Discussion of the Concepts

The three basic possibilities are:

1. FB-4 hit the upflow fault dipping at about 70° and the resource is of modest temperature.
2. FB-4 did not reach the upflow fault, which may be dipping at 80° or greater, and higher temperature resource can be found within the fault at greater depth beneath the present bottom of the hole.
3. The real upflow fault is at some horizontal distance for the FB-4 Well. Reasonably, it may be coming from the faulting observed to the west; however, it could also be coming from the faulting to the north.

Each of these possibilities is reasonable from the information in-hand. The permeability and hot water inflow encountered in the 3,000 ft to 3,600 ft depth range could be associated with either the faulting as projected, or a brecciated lava flow. The temperature logging of the hole after the bridge is cleared and well thermally stabilized may help determine which it is.

Similarly, the location of the bridge in the hole could be associated with either of these possibilities. It is common for a hole to bridge off where it passes through a fault zone. Within the fault zone, the rock is fragmented and often partially altered to clay. It tends to slough into the hole. However, it is also possible that a piece of the fractured lava flow fell out of the side of the hole and created the bridge.

One way to evaluate possibility 2 above would be to wait for and then measure a good stabilized temperature profile in the lower portion of the well after the bridge is cleared. There is a genuine possibility that the upflow fault is actually dipping steeply beneath the bottom of FB-4. It is not uncommon to measure dips of 85° on some of these Basin and Range faults. The indicators of lower temperature, e.g. the secondary clays and the geothermometry from FB-3 may not be relevant to conditions in a deeper upflow zone. It is unknown whether the relatively shallow inflow in FB-3 (2,330 ft depth) has experienced any cold water mixing that would affect the accuracy of the geothermometry calculations of anticipated deep reservoir temperature.

This approach of waiting to obtain stabilized well measurements is not being recommended, as it is far more cost-effective to simply drill additional hole as part of the clean-out operation (see section 4 below).

3.3.5. Resource Summary

The information gained from the FB-4 Well indicates the presence of a hydrothermal resource potentially capable of electrical power generation. Hence, the cost of bringing the equipment

necessary to clear the obstruction, deepen the well, and run a protective liner is justified. The recommended well operations are discussed in the following section.

4.0 Recommendation to Clean-Out, Log, and Test the Well

This section provides a recommendation to clean-out, log, and test FB-4. The testing would have two parts:

- A short “rig test” before running the liner, in order to confirm that the well’s flow potential is satisfactory.
- A longer and better-monitored test after the rig has move off the location.

It additionally provides a discussion of the recommended approach, plus cost estimates for the rig work (AFE quality) and the subsequent rig-less flow testing (order-of-magnitude).

4.1. Sequence of Operations for Clean-out and Rig Test

The following simplified sequence of operations of operations is recommended as the minimum cost-effective next action for Well FB4.

- 1) Mobilize and set-up on existing location.
- 2) Clean out bridge at 3036 ft md GL.
- 3) Drill 8-1/2” hole to total depth of 5500 ft.
- 4) Log, test, and evaluate well. (Run wireline temperature & pressure tools. Flow initiation by airlift with 2-7/8” tubing. Flow well for sufficient time to obtain stabilized thermal & chemical conditions, but limited to two days due to cost considerations. Discharge effluent to sump.)
- 5) Install 7” slotted liner if necessary. Hang liner from 100’ up inside of 9-5/8” liner. Disengage from liner hanger and pull out of hole.
- 6) Lay down drill pipe and all drilling tools.
- 7) Nipple down and clean location.
- 8) Release rig.

The addition of a sonic log to the logging activity in step 4) should also be considered as a way to potentially identify the upflow fault in the well – should it have been encountered. This log may also be able to evaluate fracture orientations in the production zone(s). This additional logging activity has not been explicitly included in this recommendation because there was insufficient time to develop the technical justification and cost estimate to do it. However, it is recommended to investigate this further.

4.2. Sequence of Operations for Rigless Flow Test

This sequence of operations is recommended if the rig test is successful and a protective slotted liner has been run. It is basically the same activities contained in the Energy Commission Grant Work Statement for the drilling of FB-4 (Barker 2005b, Task 3.3.1, page 18) as well as for the Grant Work Statement for this project (Barker 2007.) One difference is that the running of a spinner tool under flowing conditions has been added.

- Allow well to reach thermal equilibrium.
- Run wireline pressure and temperature surveys.
- Carry out design calculations to determine meter sizing, fluid sampling requirements, and instrumentation needs. Determine the need for pumping or other artificial lifting equipment to conduct the full-scale flow test. Complete the detail design and budget for test equipment and procedures.
- Mobilize tanks, separator, air compressor, pumps, and related equipment to well site.
- Rig up flow lines so the well can be surveyed with wireline tools during flow periods and so well can be killed with cold water below the master valve. Leave pressure tool or capillary tubing below expected production zone for use during flow test, at the discretion of the geothermal engineer.
- Conduct a 48-hour flow test followed by 10-day pressure buildup test. Data to be collected include fluid samples and all wellhead and flow line pressure and temperature measurements needed to accurately assess the well's commercial potential. It is anticipated that pressures and temperatures will be measured at least hourly and fluid samples taken every six hours. Extend the flow period beyond 48 hr at the discretion of the geothermal engineer.
- Run pressure, temperature and spinner surveys under flowing conditions before closing the well if well conditions permit. Resurvey at the conclusion of the pressure buildup period.
- Rig down and demobilize equipment.

4.3. Cost Estimates

An AFE quality cost estimate for the clean-out and rig test has been provided by Subsurface Excellence Inc. based on the assumption that well operations would comply with the well safety criteria of the California Division of Oil, Gas and Geothermal Resources (DOGGR). Specifically, this means that double-ram and annular blow-out prevention equipment would be installed on top of the well master valve, requiring a 12 ft sub-base.

The sequence of operations 1-8 described above is estimated to cost \$ 562,775 using prices in effect in April 2010. Details are provided in Appendix D. The costs should be inflated for future work:

- At 12% for work to be done at the end of 2010.
- An additional 12% (not compounded) for work to be done at the end of 2011.

This results in a total of 24% increase if the work is to be done at the end of 2011, as depicted in Table 1.

Table 1 – Escalation of Rig Clean-Out and Flow Test Costs

Work Done in	Estimated Cost of Steps 1-8
April 2010	\$562,775
December 2010	\$630,308
December 2011	\$697,841

Cost estimates were solicited from other drillers. One quote was received, which was both more costly than that provided by Subsurface Excellence Inc, and did not meet DOGGR well safety criteria.

A scoping cost estimate to flow test the well after the rig has been moved off location has also been developed. This is based on the originally estimated cost of \$170,200 for this activity (Barker 2005a,) escalated at 12% per year, and presented in Table 2. The cost estimates correspond to year-end.

Table 2 – Escalation of Rigless Flow Test Costs

Year	2005	2006	2007	2008	2009	2010	2011
Cost							
No spinner survey	\$170,200	\$190,624	\$213,499	\$239,119	\$267,813	\$299,951	\$335,945
With spinner survey						\$319,951	\$355,945

The basis for the original 2005 cost estimate is not available. It is recommended to re-develop current costs by obtaining quotes from qualified service providers.

The following text from Barker (2005a) is also pertinent to the cost estimate presented in here.

... Note that well testing entails bringing equipment back onto the site after the rig is removed and the well has reached thermal equilibrium. The well testing budget actually serves more than one purpose. If the well is unsuccessful, the well testing portion of the budget will instead, be used to convert the well to a direct use well. If perforation of the casing is necessary, the monies included for well testing should cover it. In the remote possibility of the well being entirely useless, this budget would cover plug and abandonment of the well.

5.0 Technology Transfer

The results of this project were presented orally at the 2010 Annual Meeting of the Geothermal Resources Council, held in Sacramento, California, October 24-27. They have also been published in the conference proceedings (LaFleur et al, 2010).

6.0 Summary and Recommendations

The existence of a bridge shortly below the casing shoe in FB-4 has prevented continued testing and evaluation of the well and resource. This report has:

- Collected together and summarized what is known about the resource and well.
- Concluded that there is no new information invalidating the original hydrothermal concept and resource estimate made before it was drilled.
- Provided a recommendation for sequence of operations and associated cost estimate to proceed with well clean-out and testing.

7.0 References

- Atkinson, D.J. (1981), "Geology, Geophysics, and Hydrogeology of the Fort Bidwell Area, and the Drilling of Geothermal Well FB-1," prepared for the Fort Bidwell Indian Tribal Council under California Energy Commission Contract 500-79-069, Appendix II, December.
- Barker (2005a), "Fort Bidwell Indian Community, Geothermal Exploration Drilling, Assessment and Demonstration in Indian Country, Volume 2: Technical And Cost Information" CEC GRDA Resource Development, Final Application, Section 8, pg. 33.
- Barker (2005b), "Work Statement - Fort Bidwell Indian Community - Exploration Drilling, Assessment and Demonstration in Indian Country," grant number GEO-05-002, Task 3.1, pg. 16.
- Barker (2007), "Work Statement - Fort Bidwell Indian Community - Fort Bidwell Reservation Geothermal Well Test," grant number GEO-07-004, Task 2.2, pg. 9.
- Hamblin, J. (2010), personal communication, March 10.
- Juncal, R.W. (1984), "Technical Summary, Drilling and Testing of Exploratory Well FB-2," Fort Bidwell Indian Community Council report (049-9014), Figure 2.1, December.
- LaFleur, J. (2005), "Phase I Technical Report, DE-FG36-04GO14343 (GRED III), Geothermal Resource Exploration and Definition of the Fort Bidwell Indian Reservation Hydrothermal System," U.S. Department of Energy Geothermal Technology Program, pp. iv-v and 28-30, August 9.
- LaFleur, J. (2007a), "Final Report - Technical Report and Lessons Learned, CEC GRDA GEO-05-002, Geothermal Exploration Drilling, Assessment and Demonstration in Indian Country" unpublished report, November.
- LaFleur, J. (2007b), "Phase II - Drilling, Technical Report And Issues Addressed/Lessons Learned, DE-FG36-04GO14343 (DOE GRED III), Geothermal Resource Exploration and Definition of the Fort Bidwell Indian Reservation Hydrothermal System," unpublished report, November.
- LaFleur, J., Carter, A., Moore, K., Barker, B., Atkinson, P., Jones, C., Moore, J. and Pollard B. (2010), "Update on Geothermal Exploration at Fort Bidwell, Surprise Valley California", GRC Transactions, Vol. 34, pp. 581-583.
- Lawrence, D.A. (1985), "Drilling Report, Fort Bidwell Geothermal Test Hole 3, Located at Fort Bidwell Indian Reservation, Modoc County, California," Prepared for Fort Bidwell Indian Community Council, Figure 2, September 9.

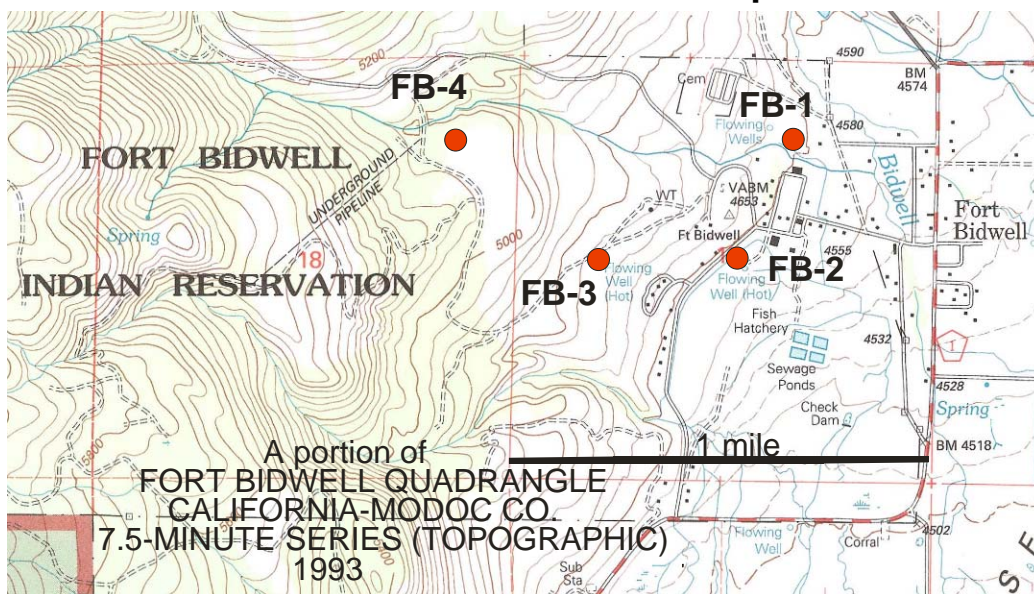
USDOE (2009), "Financial Assistance Funding Opportunity Announcement - Recovery Act: Geothermal Technologies Program," Funding Opportunity Announcement Number: DE-FOA-0000109, Topic Area 2 discussion on pages 2 & 9, May 27.

APPENDIX A – Well Data – FB-4, FB-3, FB-2, and FB-1

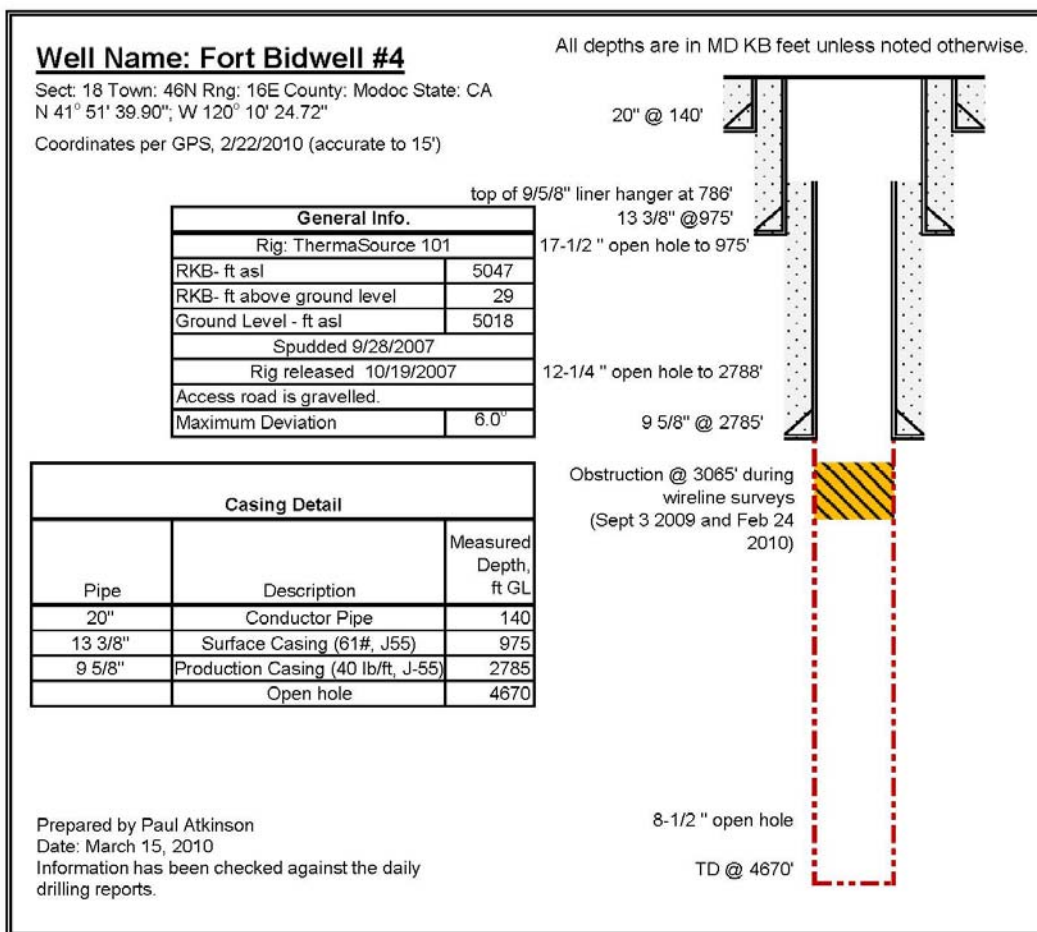
This Appendix contains the test and reservoir data acquired during the project.

- A location topographic map for Fort Bidwell, showing the location of the wells FB-1 through FB-4.
- Well FB-4 information not presented in the final report submitted to the California Energy Commission in November 2007 following completion of the well. This includes the current well schematic, master valve information, plus narrative descriptions of activity at the well on September 3, 2009, February 24 & March 12, 2010. In conjunction with the well drilling information provided in the November 2007 report (Daily Drilling Reports and Mud Log) this information provides most of the information that would normally be found in a well file.
- Well FB-4 Cuttings Analysis “Petrographic and X-ray diffraction analyses of cuttings from geothermal well Fort Bidwell-4” carried out by Clay Jones and Joseph Moore of the Energy & Geoscience Institute at the University of Utah.
- Well FB-3 well schematic, temperature & spinner survey on May 18, 1987 and report of activity on September 3, 2009.
- Well FB-2 well schematic.
- Well FB-1 Water Well Drillers Report.

A-1. Fort Bidwell Geothermal Wells Location Map



A-2. Well FB-4 Schematic and Description of Activity



Master Valve Description (taken from plate attached to the valve)

WKM 9/07; Size 12 3/8 WKM; OEM SN 121466-3; Class 400

TNG SN 42-10; RPR/RMFR RPR; Trim GEO

TNG Energy Services; Repair, Remanufacture, Bakersfield, CA; ph 661-323-7031

March 12, 2010 Well Activity Report

Pacific Process Systems, Inc. (P.P.S.) installed the following top flange and other equipment on top of the well master valve.

Description
12" 400 series flange w/ 3" threads
3" X 8" nipple
3" Ball Valve
3" plug
Bolts and nuts 16
API Ring

February 24, 2010 Well Activity Report

TAG FILL REPORT ON FT. BIDWELL # 4 2/24/2010

[...]

This tool string consisted of 8' 1 ¼" sinker bar, 5' spang jars w/ a 20" stroke. Total weight of tool string was 125#.

[...]

Arrived on location @ 11:00 a.m.

Held tailgate safety meeting. Checked location for safety hazards.

MIRU.RIH/w 1 ¼" spear, tagged bttm. @ 3036'. Jarred down and tried to break through but to no avail. POOH.

RIH w/2 ½" Barrel Grab and sat down on T.O.L. @ 764'. Tried, but could not get past. POOH.

RIH w/1 ½" sample bailer to fill @ 3036, and retrieved sample. POOH

Gave sample to Paul Atkinson and RDMO.

Ken Pitts

Samples of rock particles were examined by Joe LaFleur, who submitted the following report on March 1, 2010.

I have washed, dried, and examined the rock fragments collected from the top of the bridge at 3036' in the FB-4 well. The fragments contain a collection of different

volcanic rock types suggesting that the bridge is composed of fill or slough and/or drill cuttings, rather than a singular rock that fell and jammed. By far the dominant rock type is a soft but well-indurated, clay-rich mafic lithic tuff that quickly develops desiccation cracks upon drying.

The bridge could have resulted from sloughing of the sides of hole in the uncased interval between 2765' and the top of the bridge at 3036'. The bridge could also consist of cuttings that were not cleared from the hole at the end of drilling, perhaps having been pushed back into a crack or cavity in the formation during the drilling process.

September 3, 2009 Survey Results

Pressure and Temperature Survey

WELL: FB-4

API#: N/A

DATE: 9/03/2009

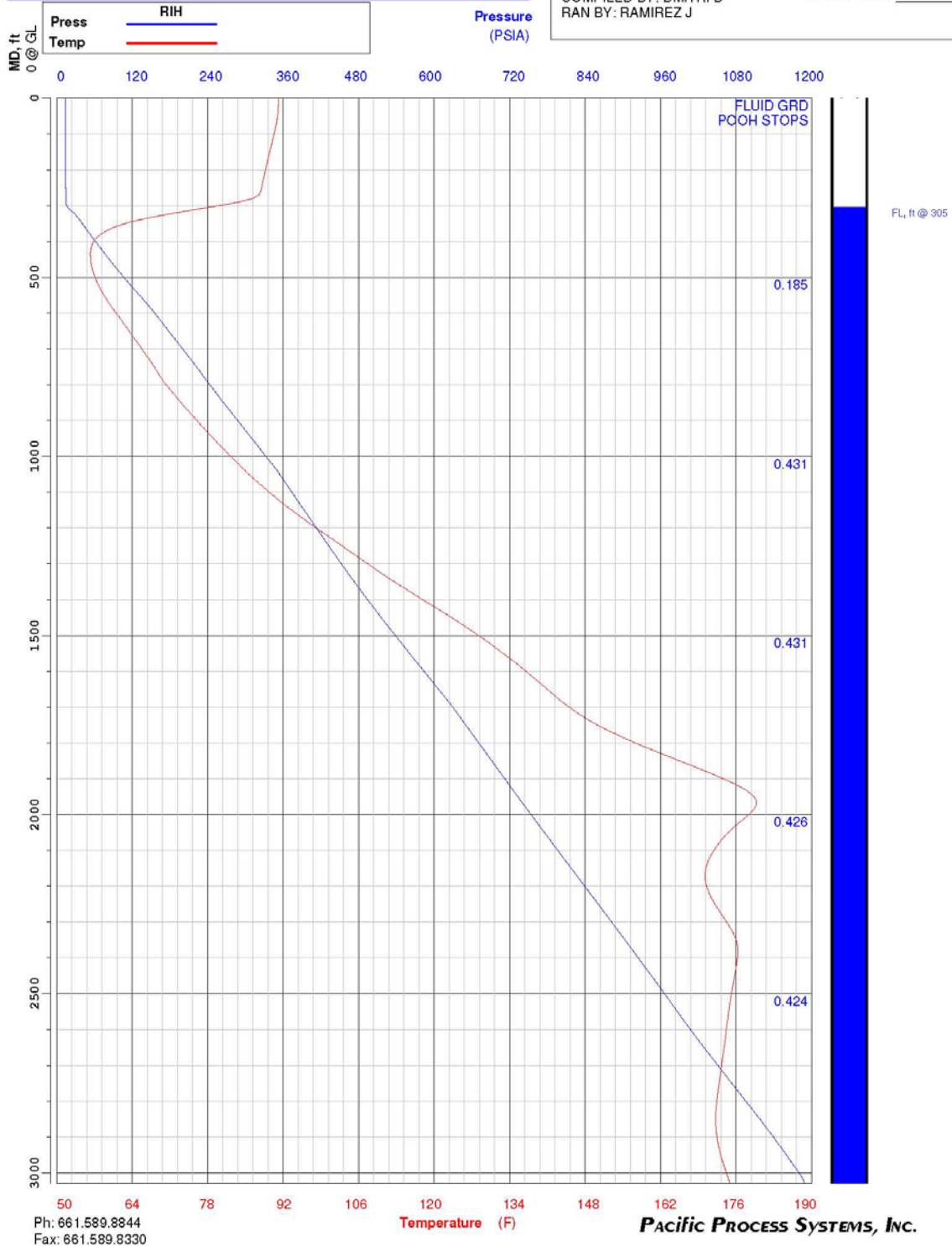
COMPANY: Fort Bidwell Indian Community

FIELD: FBIC

STATE: CA

FLUID LEVEL ft: 305
TOTAL DEPTH, ft: N/A
TOTAL LOGGED DEPTH, ft: 3030
TAG DEPTH, ft: 3030
TBG, psia: 14
CSG, psia: N/A
COMPILED BY: DMITRI B
RAN BY: RAMIREZ J

TBG, in: N/A
CSG, in: N/A
PKR DEPTH, ft: N/A
TBG TAIL, ft: N/A
STATUS: Static
GAUGE #: 5706/5716
COMMENTS:



RIH		
DEPTH (FT)	TEMP (F)	PRESS (PSIA)
0	91.11	14.28
10	91.10	14.28
20	91.09	14.28
30	91.07	14.27
40	91.02	14.27
50	90.94	14.28
60	90.84	14.28
70	90.72	14.28
80	90.59	14.28
90	90.45	14.28
100	90.29	14.28
110	90.13	14.28
120	89.97	14.28
130	89.81	14.28
140	89.65	14.28
150	89.49	14.28
160	89.33	14.28
170	89.17	14.28
180	89.02	14.28
190	88.86	14.28
200	88.71	14.28
210	88.56	14.28
220	88.41	14.28
230	88.27	14.28
240	88.12	14.28
250	87.98	14.28
260	87.84	14.29

RIH		
DEPTH (FT)	TEMP (F)	PRESS (PSIA)
1010	82.94	337.08
1020	83.60	341.58
1030	84.28	346.10
1040	84.97	350.43
1050	85.68	354.33
1060	86.40	358.26
1070	87.13	362.15
1080	87.87	365.97
1090	88.64	369.77
1100	89.41	373.61
1110	90.20	377.52
1120	91.01	381.49
1130	91.83	385.43
1140	92.68	389.38
1150	93.55	393.31
1160	94.45	397.31
1170	95.36	401.19
1180	96.28	405.17
1190	97.21	409.10
1200	98.15	412.92
1210	99.10	416.74
1220	100.06	420.66
1230	101.03	424.57
1240	101.99	428.55
1250	102.94	432.52
1260	103.89	436.48
1270	104.84	440.44

RIH		
DEPTH (FT)	TEMP (F)	PRESS (PSIA)
2020	176.71	762.38
2030	175.93	766.59
2040	175.19	770.91
2050	174.49	775.17
2060	173.85	779.45
2070	173.27	783.65
2080	172.75	787.89
2090	172.26	792.16
2100	171.83	796.48
2110	171.43	800.77
2120	171.08	805.04
2130	170.79	809.34
2140	170.55	813.63
2150	170.37	817.91
2160	170.26	822.20
2170	170.21	826.48
2180	170.24	830.81
2190	170.33	835.08
2200	170.49	839.37
2210	170.70	843.64
2220	170.97	847.89
2230	171.28	852.17
2240	171.63	856.46
2250	172.01	860.73
2260	172.43	865.04
2270	172.86	869.31
2280	173.30	873.59

270	87.57	14.30	1280	105.79	444.36	2290	173.75	877.86
280	86.48	14.30	1290	106.75	448.28	2300	174.19	882.12
290	83.86	14.47	1300	107.70	452.24	2310	174.62	886.37
300	80.16	15.47	1310	108.65	456.41	2320	175.01	890.61
310	76.10	20.20	1320	109.60	460.57	2330	175.37	894.87
320	72.22	26.78	1330	110.58	464.74	2340	175.69	899.11
330	68.57	32.13	1340	111.58	468.86	2350	175.94	903.32
340	65.35	36.46	1350	112.59	472.94	2360	176.13	907.50
350	62.74	40.64	1360	113.64	477.10	2370	176.24	911.74
360	60.74	44.71	1370	114.69	481.27	2380	176.28	915.97
370	59.25	48.79	1380	115.74	485.44	2390	176.26	920.17
380	58.17	53.01	1390	116.81	489.75	2400	176.20	924.31
390	57.41	57.21	1400	117.87	494.03	2410	176.12	928.46
400	56.88	61.38	1410	118.94	498.39	2420	176.02	932.65
410	56.53	65.58	1420	120.01	502.81	2430	175.92	936.79
420	56.32	70.02	1430	121.08	507.08	2440	175.81	941.05
430	56.22	74.54	1440	122.15	511.45	2450	175.69	945.28
440	56.20	79.00	1450	123.21	515.81	2460	175.57	949.47
450	56.24	83.46	1460	124.25	520.23	2470	175.45	953.57
460	56.34	87.99	1470	125.27	524.69	2480	175.33	957.74
470	56.48	92.54	1480	126.27	529.21	2490	175.21	961.88
480	56.65	97.14	1490	127.26	533.68	2500	175.10	966.06
490	56.86	101.80	1500	128.23	538.14	2510	174.99	970.22
500	57.10	106.50	1510	129.18	542.69	2520	174.88	974.32
510	57.37	111.46	1520	130.12	547.27	2530	174.78	978.39
520	57.67	116.42	1530	131.03	551.86	2540	174.68	982.53
530	58.01	121.40	1540	131.92	556.33	2550	174.59	986.61
540	58.37	126.46	1550	132.79	560.85	2560	174.50	990.74
550	58.76	131.47	1560	133.66	565.41	2570	174.41	994.82
560	59.17	136.42	1570	134.50	569.96	2580	174.33	998.90
570	59.61	141.38	1580	135.33	574.59	2590	174.25	1003.10

580	60.07	146.44	1590	136.15	579.19	2600	174.18	1007.37
590	60.54	151.34	1600	136.96	583.85	2610	174.09	1011.69
600	61.03	155.85	1610	137.75	588.44	2620	174.01	1015.96
610	61.52	160.16	1620	138.54	593.00	2630	173.93	1020.22
620	62.00	164.54	1630	139.31	597.62	2640	173.84	1024.57
630	62.48	168.97	1640	140.09	602.23	2650	173.75	1028.98
640	62.95	173.40	1650	140.86	606.85	2660	173.66	1033.38
650	63.43	177.84	1660	141.65	611.49	2670	173.57	1037.80
660	63.90	182.37	1670	142.44	616.11	2680	173.47	1042.13
670	64.37	186.79	1680	143.24	620.80	2690	173.38	1046.46
680	64.84	191.28	1690	144.07	625.36	2700	173.29	1050.85
690	65.31	195.79	1700	144.95	629.52	2710	173.20	1055.24
700	65.78	200.26	1710	145.88	633.62	2720	173.10	1059.70
710	66.25	204.65	1720	146.85	637.76	2730	173.01	1064.15
720	66.72	209.03	1730	147.90	641.91	2740	172.92	1068.63
730	67.18	213.47	1740	149.01	646.07	2750	172.83	1073.06
740	67.63	217.84	1750	150.22	650.19	2760	172.73	1077.50
750	68.07	222.09	1760	151.49	654.31	2770	172.64	1081.92
760	68.49	226.48	1770	152.83	658.42	2780	172.55	1086.37
770	68.90	230.71	1780	154.23	662.50	2790	172.47	1090.74
780	69.33	234.96	1790	155.69	666.66	2800	172.39	1095.19
790	69.79	239.15	1800	157.20	670.87	2810	172.32	1099.73
800	70.29	243.37	1810	158.78	675.06	2820	172.26	1104.30
810	70.83	247.71	1820	160.40	679.20	2830	172.22	1108.80
820	71.37	252.01	1830	162.06	683.34	2840	172.19	1113.35
830	71.94	256.40	1840	163.72	687.42	2850	172.18	1117.74
840	72.50	260.80	1850	165.40	691.56	2860	172.18	1122.05
850	73.06	265.24	1860	167.07	695.75	2870	172.21	1126.39
860	73.64	269.72	1870	168.75	699.88	2880	172.25	1130.69
870	74.22	274.21	1880	170.40	704.01	2890	172.32	1135.02
880	74.81	278.69	1890	172.00	708.12	2900	172.41	1139.23

890	75.40	283.16	1900	173.54	712.24	2910	172.52	1143.26
900	76.00	287.68	1910	174.99	716.37	2920	172.65	1147.29
910	76.61	292.19	1920	176.32	720.54	2930	172.79	1151.27
920	77.21	296.67	1930	177.50	724.76	2940	172.95	1155.27
930	77.82	301.12	1940	178.50	728.93	2950	173.11	1159.25
940	78.44	305.59	1950	179.25	733.10	2960	173.29	1163.25
950	79.06	310.12	1960	179.68	737.19	2970	173.49	1167.22
960	79.69	314.60	1970	179.75	741.40	2980	173.70	1171.21
970	80.32	319.09	1980	179.49	745.58	2990	173.92	1175.21
980	80.97	323.56	1990	178.98	749.74	3000	174.15	1179.19
990	81.61	328.05	2000	178.29	753.94	3010	174.39	1183.14
1000	82.27	332.58	2010	177.51	758.17	3020	174.63	1186.39
						3030	174.86	1189.45

POOH			
STOPS (FT)	TEMP (F)	PRESS (PSIA)	FLUID GRD PSI/FT
0	55.46	14.29	
500	61.48	107.03	0.185
1000	89.07	322.68	0.431
1500	136.73	537.95	0.431
2000	173.47	750.84	0.426
2500	174.31	962.61	0.424
3030	176.16	1186.21	0.422

September 3, 2009 Well Activity Report

-----	Forwarded	Message	-----
From:	"Ben Barker"	<benbarker@earthlink.net>	
To:	"John Vass"	<johnvass@citlink.net>	
Sent:	Saturday, September 19, 2009	8:42:47 AM GMT	-08:00
	US/Canada		Pacific
Subject:	Update	on	testing

Here is the status of the testing program.

Pacific Process Systems (PPS) logged well FB-4 on Sept. 3 with mixed results. PPS's first run with temperature and pressure tools set down on an obstruction at 3030 feet below ground level. This depth is 245 feet below casing in the open hole section and 1603 feet above the drilled total depth of 4633 feet. The logging tools indicated a temperature of about 180 F at 3000 feet, substantially lower than expected. However, the pressure tool readings indicated a measurement system failure and PPS changed that tool reran the survey.

The second survey showed the same obstruction depth and temperature with consistent pressure readings. The pressure readings show a standing liquid level in FB-4 at 300 feet below ground level. This is an encouraging result that indicates FB-4's pressure is controlled by the same hot water system that FB-3 found.

PPS did not have a full suite of tools for dealing with problems in open hole and was not able to confirm whether the obstruction at 3030 ft was a ledge or a bridge. However, the low temperature points to a bridge, which is preventing the circulation of hot water into the well.

[...]

A-3. Well FB-4 Cuttings Analysis

"Petrographic and X-ray diffraction analyses of cuttings from geothermal well Fort Bidwell-4" by Clay Jones and Joseph Moore of the Energy & Geoscience Institute at the University of Utah.

Introduction

Well cuttings from Fort Bidwell-4 were collected at 10' intervals from 130 to 4660 ft. From these cuttings 38 thin-sections have been made at roughly 100 ft intervals from 980 to 4660 ft. Over the same depth range, 18 samples (~200' intervals) were prepared for X-ray diffraction (XRD) analysis to identify the clay minerals in each sample. Chip boards were also prepared and examined by binocular microscope.

Lithologies

Thin sections and chip boards were examined in order to differentiate and describe lithologies. A lithologic column (Figure 9) and lithologic descriptions are presented.

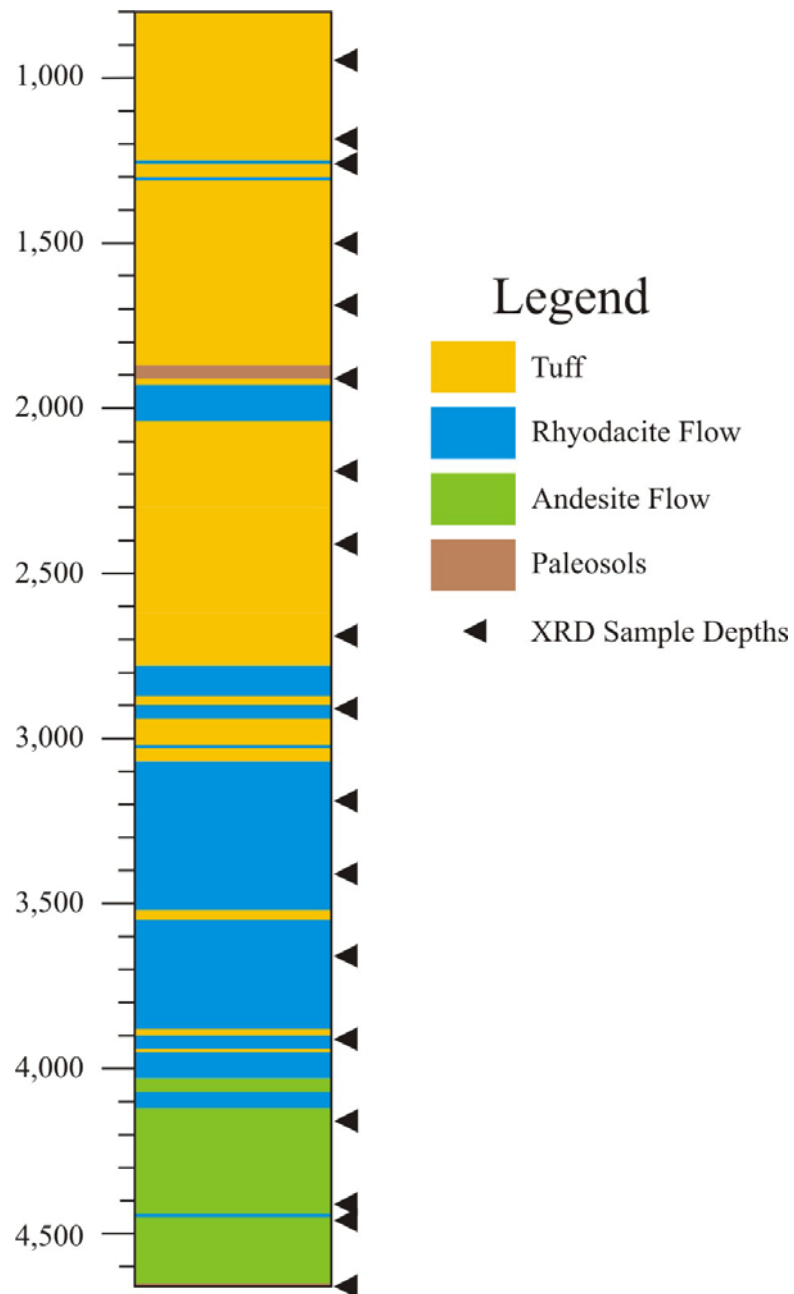


Figure 9 – Lithologic Column Constructed for Well FB4 With Information From Thin Sections and Cuttings. Legend Showing Lithologies on the Right; Triangles Mark Depth at Which the Clay-Sized Fraction Was Analyzed Using XRD Methods (see below).

Tuffs

The ash flow tuffs are generally poorly welded, crystal-poor, and lithic-rich (Figure 10). However phenocrysts are observed, in decreasing order of abundance they are: plagioclase, biotite, quartz, sanidine, magnetite, and possibly pyroxene (now altered). Pumice fragments are the most common constituents of the tuff in the upper portions of the well, with the volume of lithic fragments increasing with depth, and pumice decreasing. Variable proportions of rhyolite, volcanic glass, and andesite are often found within the same sample, and pumice shards become increasingly rare. Zeolites (clinoptilolite?) and calcite fill void spaces. XRD analysis indicates that illite, smectite, and kaolinite are the dominant clay minerals within the tuffs.

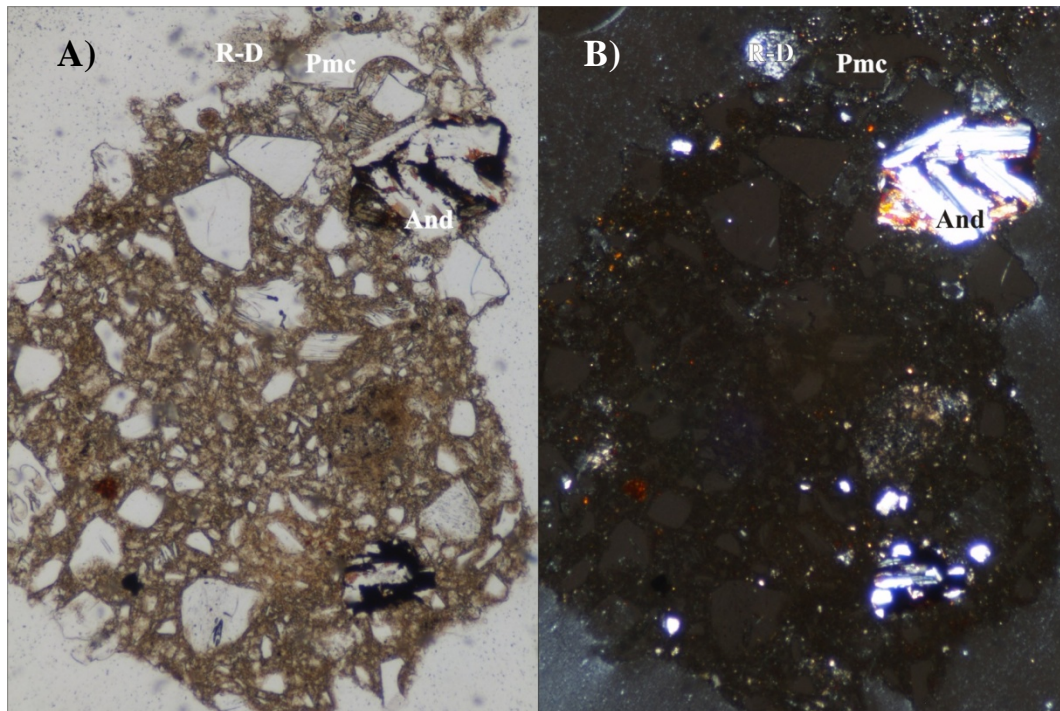


Figure 10 – Chip of a Tuff From Well FB4 Containing Abundant Pumice Shards (Pmc) as well as Lithic Fragments of Rhyodacite (R-D) and Andesite (And). A) Plane Polarized Light. B) Crossed Nicols. Field of View is 3.4 mm Across.

Rhyodacite Flows

The upper rhyodacites range from glassy to fine-grained (Figure 11) and may be flow-banded, vesicular, auto-brecciated and/or devitrified. Plagioclase is the most common phenocryst, with smaller abundances of biotite, hornblende, and tourmaline. Devitrification of the matrix has produced fine-grained mixtures of quartz and K-feldspar. Zeolites are present as vug fillings. XRD analysis indicates that illite, smectite, and kaolinite occur within the rhyodacite flows.

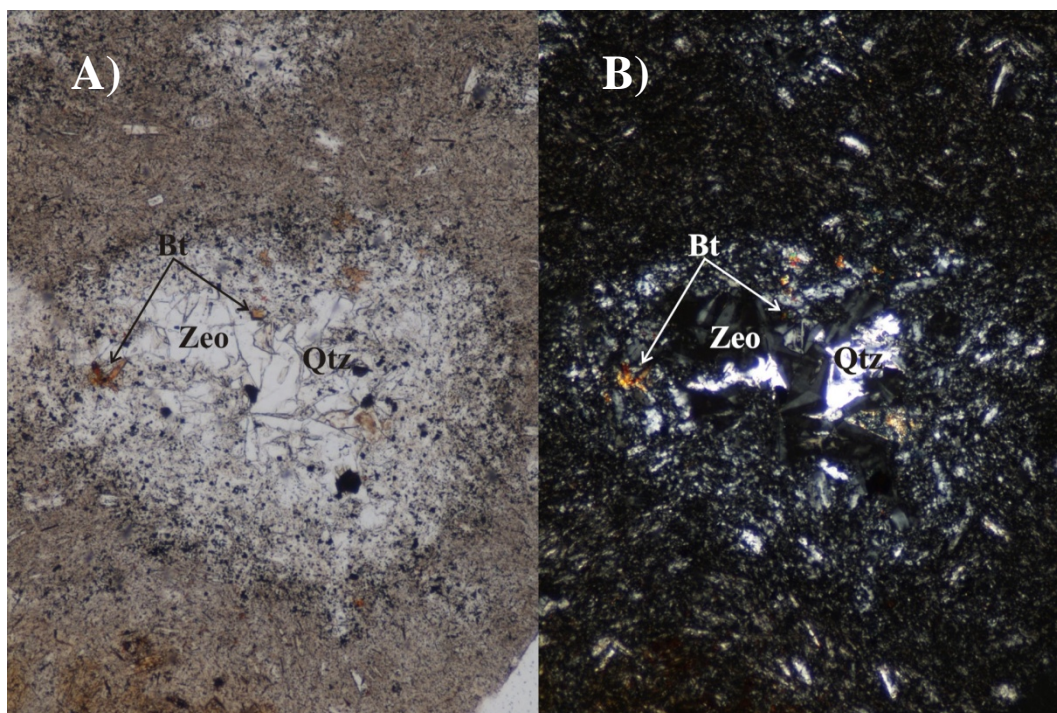


Figure 11 – Fine-Grained Rhyodacite Flow Consisting of Tabular Plagioclase Laths in a K-feldspar Rich Matrix. The Vesicle in This Image Is Filled With a Zeolite (Zeo) Possibly Stilbite and Quartz (Qtz), With a Few Biotite (Bt) Phenocrysts Seen Near The Edge. A) Plane Polarized Light. B) Crossed Nicols. Field of View is 1.7 mm Across.

Andesite Flows

The andesitic flows vary from glassy to coarse-grained (Figure 12). The coarse-grained chips contain interlocking plagioclase laths with clinopyroxene and magnetite filling the interstices. Fine-grained and glassy flow material can contain plagioclase, pyroxene, hornblende, biotite, and apatite phenocrysts. These andesitic flows are locally brecciated and extensively altered. Smectite is a common alteration phase after plagioclase, pyroxene, and glass. Quartz, calcite, clays (smectite and chlorite), zeolites (wairakite and analcime), and chalcedony fill open space.

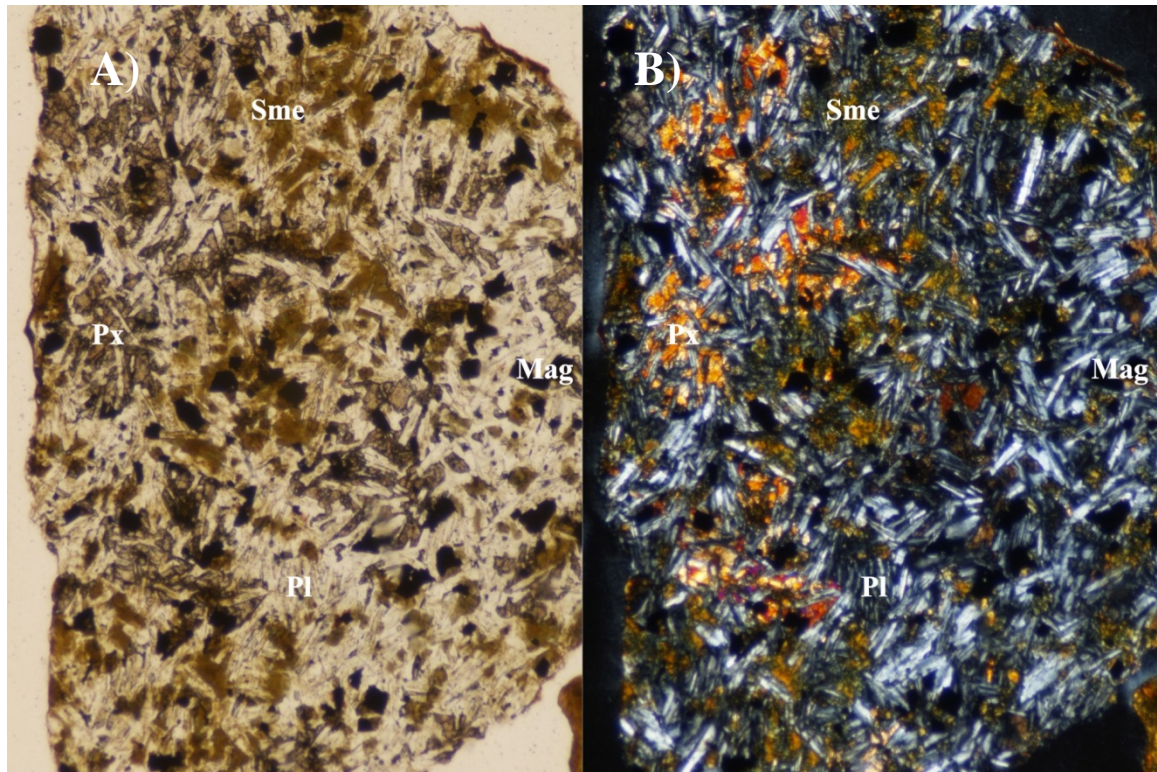


Figure 12 – Coarse-Grained Andesite Composed of Interlocking Plagioclase (Pl) Laths, With Pyroxene (Px) and Magnetite (Mag) Filling Interstices. Much of the Pyroxene Has Been Altered to Smectite (Sme). A) Plane Polarized Light. B) Crossed Nicols. Field of View is 3.4 mm Across.

Paleosols

Mineral grains, rock fragments, and pieces of wood are supported by a red-black matrix, possibly consisting of clays and organic matter(?) stained by hematite (Figure 13).

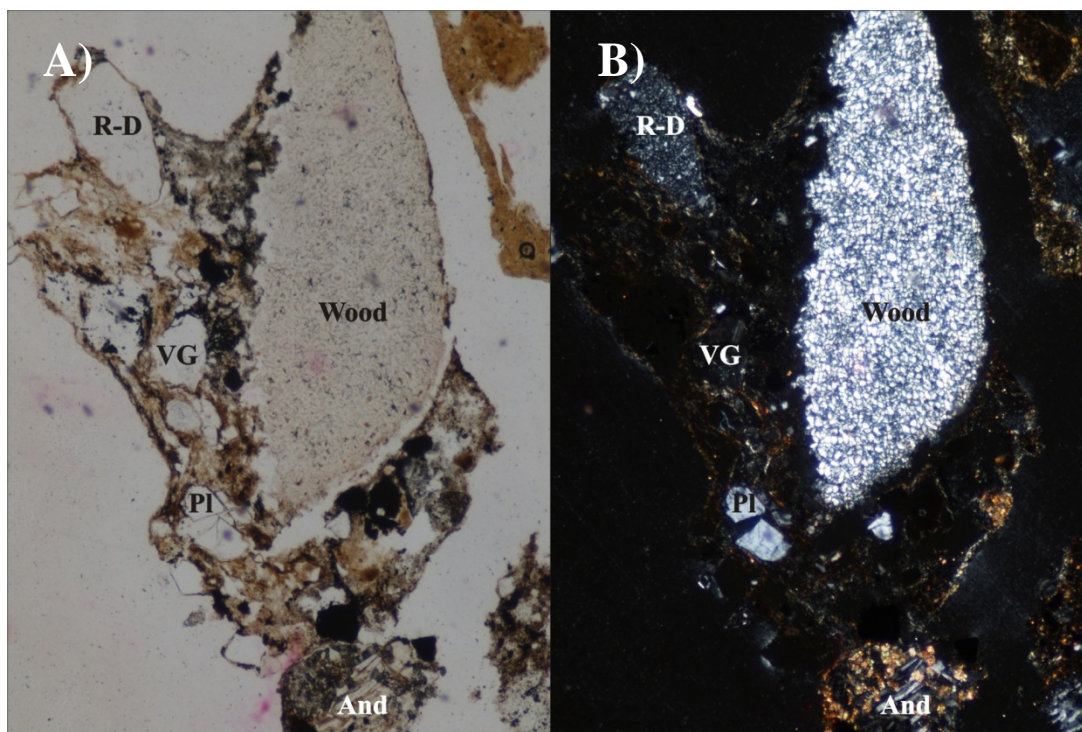


Figure 13 - A Fragment of Wood in a Paleosol, Which is a Matrix Supported Rock Containing Fragments of Volcanic Glass (VG), Rhyodacite Flow (R-D), Andesite Flow (And), and a Broken Plagioclase Grain. A) Plane Polarized Light. B) Crossed Nicols. Field of View is 3.4 mm Across.

X-Ray Diffraction Methodology

XRD analyses of the clay sized fraction (<5 micrometer fraction) of each sample were performed in the XRD laboratory at the Energy & Geoscience Institute at the University of Utah. A Phillips XRG 3100 generator emitting Cu-K- α radiation at 40 kV and 40 mA was used for the analyses. The instrument is equipped with a vertical goniometer, and a compensating slit designed to provide constant sample irradiation.

The samples were ground in a micronizing mill until fine enough to pass through a 325 mesh screen (particle size < 44 micrometers). The clay fraction was separated from the bulk sample using Stokes Law for particle sedimentation. After air-drying, the samples were scanned from 2° to 45° 2θ with a 0.75° 2θ step size. The samples were then allowed to interact with ethylene glycol vapors to induce swelling of smectite-bearing clays and additional X-ray diffraction scans were performed. The air-dried and glycolated patterns were then compared to determine which, if any, smectite-bearing clays were present. Clay abundances were determined from the whole-rock scans.

Clay minerals are particularly sensitive to temperature and thus can be used as a mineral geothermometer. The persistence of smectite throughout the rock sequence (Figures 14 & 15) suggests that temperatures during hydrothermal alteration have not

exceeded approximately 180°C. At higher temperatures interlayered illite-smectite would be anticipated. No interlayered clays were found.

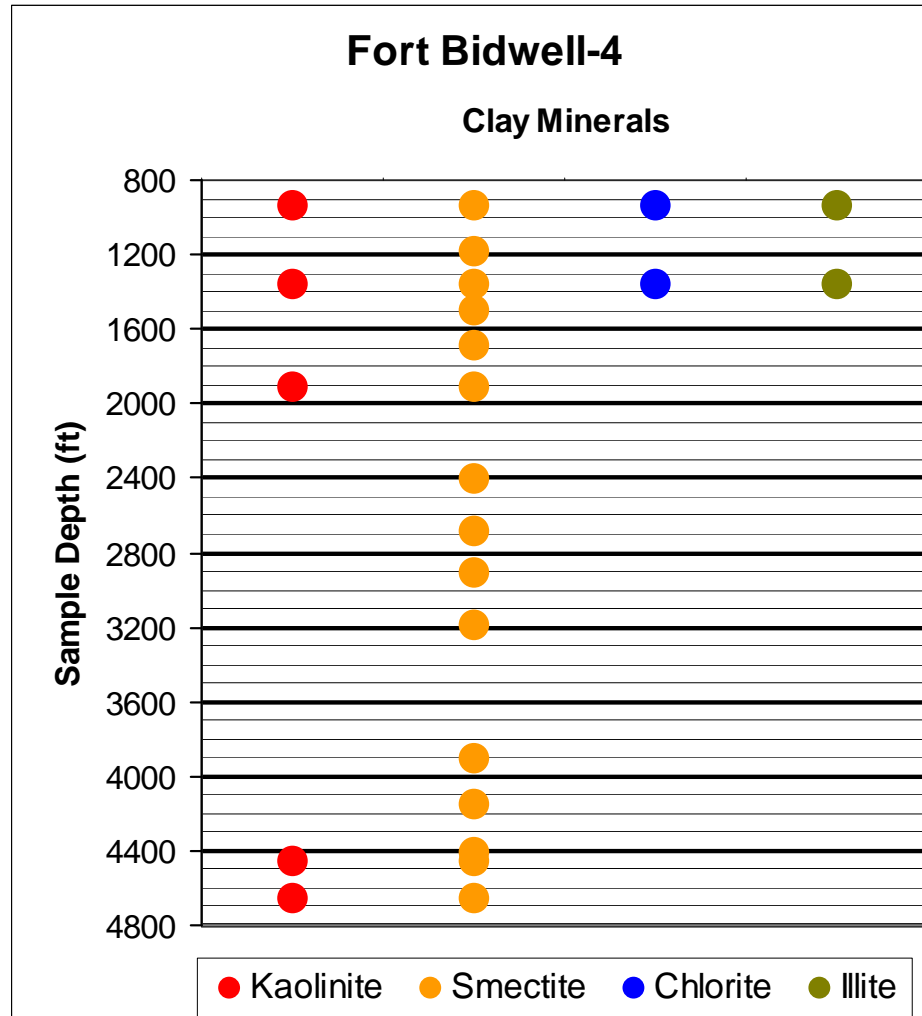


Figure 14 – Clay Minerals Identified by XRD Methods Plotted Versus Depth Below Kelly Bushing for Well FB4.

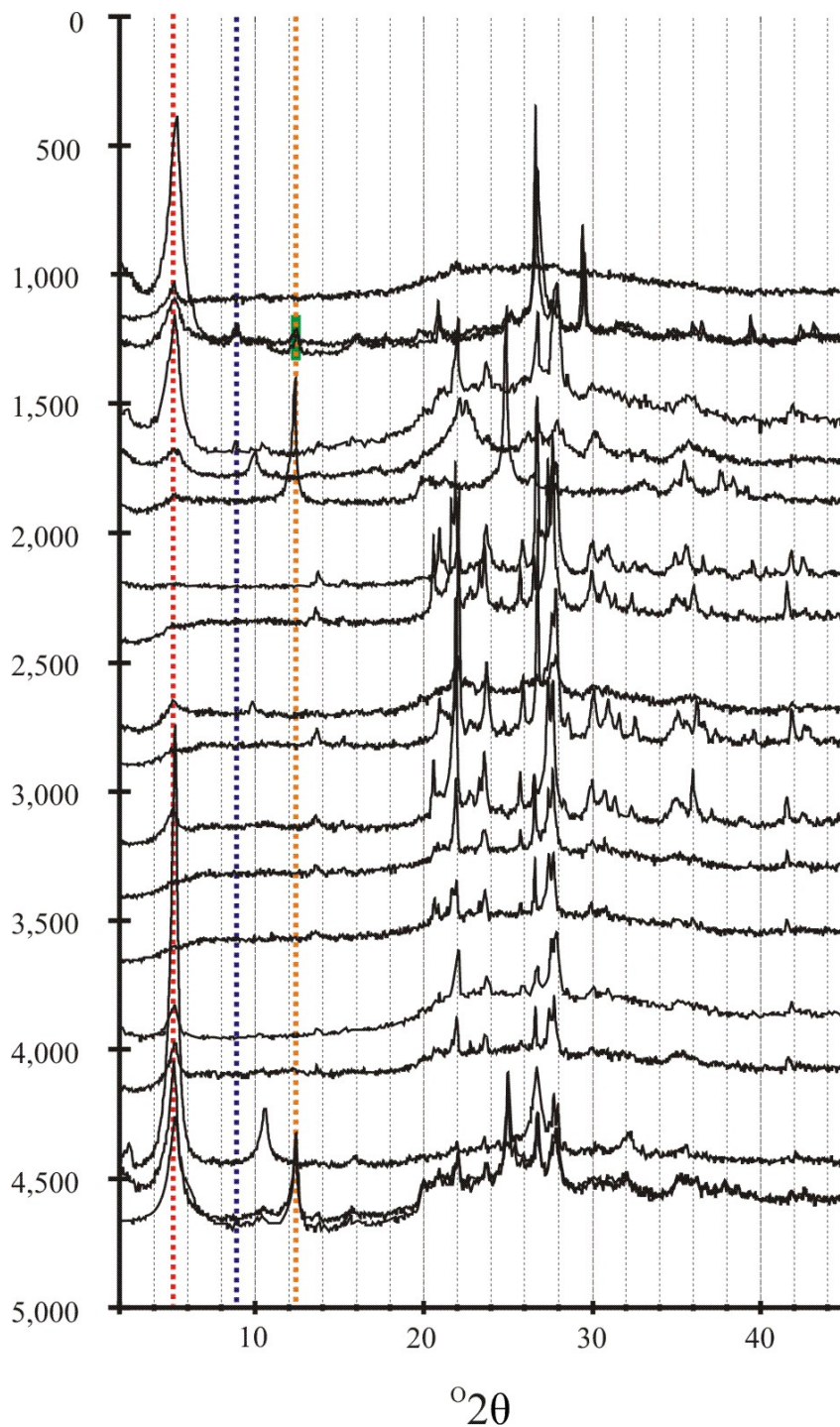


Figure 15 – XRD Plot of the Ethylene Glycol-Solvated Clay Sized Fraction Versus Depth for Well FB4. The Point at Which the Scan Line Crosses the Left Edge of the Plot Is Its Approximate Depth Below Kelly Bushing in Feet. Red Dotted Line Shows the Location of the Primary Smectite Peak, Blue Illite, and Orange Kaolinite, and Short Solid Green is Only Drawn in the Area Where the Main Chlorite and Kaolinite Peaks Overlap.

A-4. Well FB-3 Activity Reports and Well Schematic

September 3, 2009 Well Activity Report

```
----- Forwarded Message -----
From:      "Ben      Barker"      <benbarker@earthlink.net>
To:        "John      Vass"        <johnvass@citlink.net>
Sent:      Saturday, September 19, 2009 8:42:47 AM GMT -08:00
US/Canada
Subject:    Update on testing
```

Here is the status of the testing program.

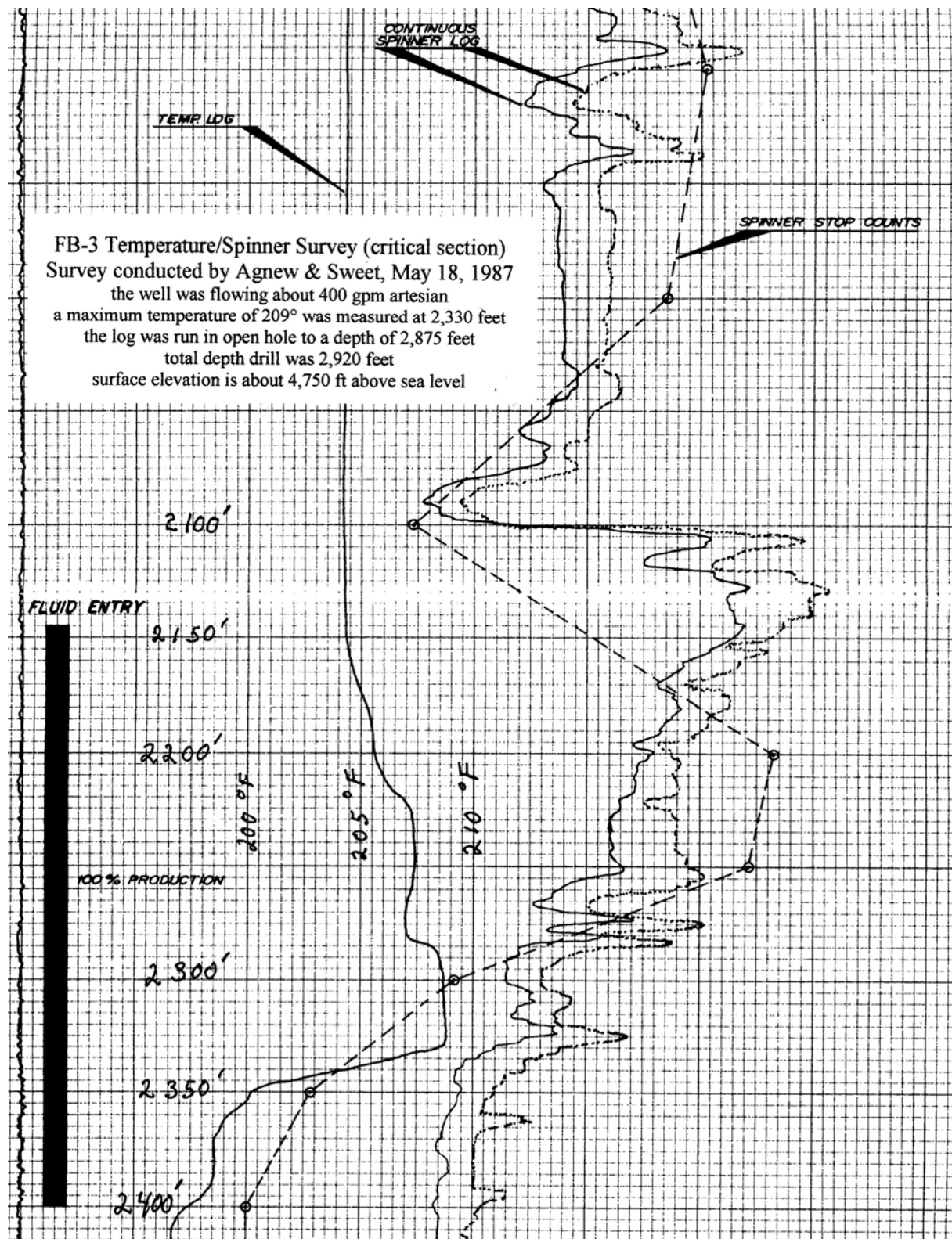
Pacific Process Systems (PPS) logged well FB-4 on Sept. 3 ...

[...]

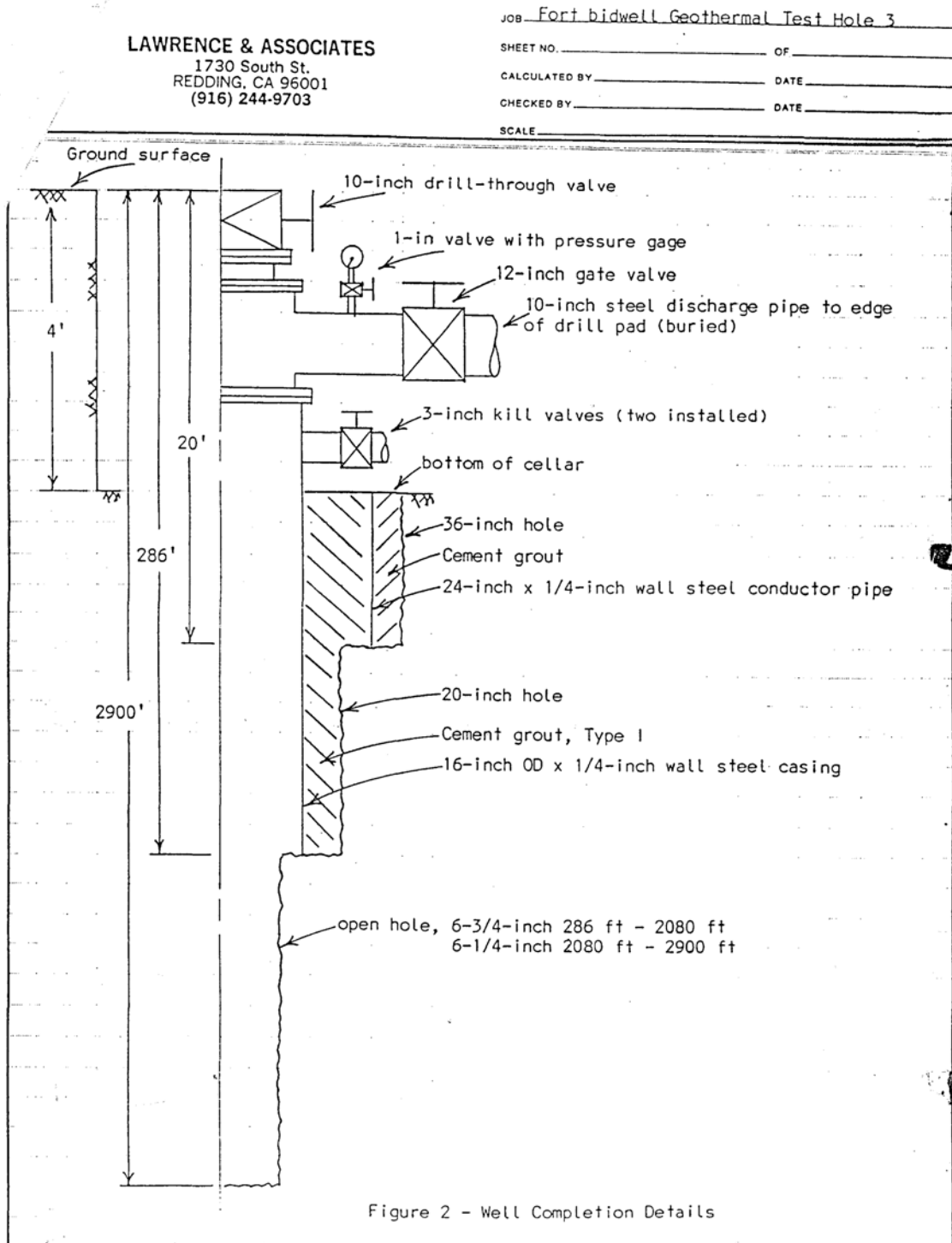
A positive result of PPS's visit was the opportunity to check the condition of FB-3. PPS wanted to check their tool function after the initial problem at FB-4, so I rigged them up on FB-3. Their tools set down at 267 feet on the large ledge at the casing shoe, but we were then able to flow the well and observe that its flowing rate and temperature have apparently not diminished.

[...]

Temperature/Spinner Survey on May 18, 1987 (from LaFleur 2005, pg. 19)



Well FB-3 Schematic (Lawrence 1985.)



A-5. Well FB-2 Schematic (Juncal 1984)

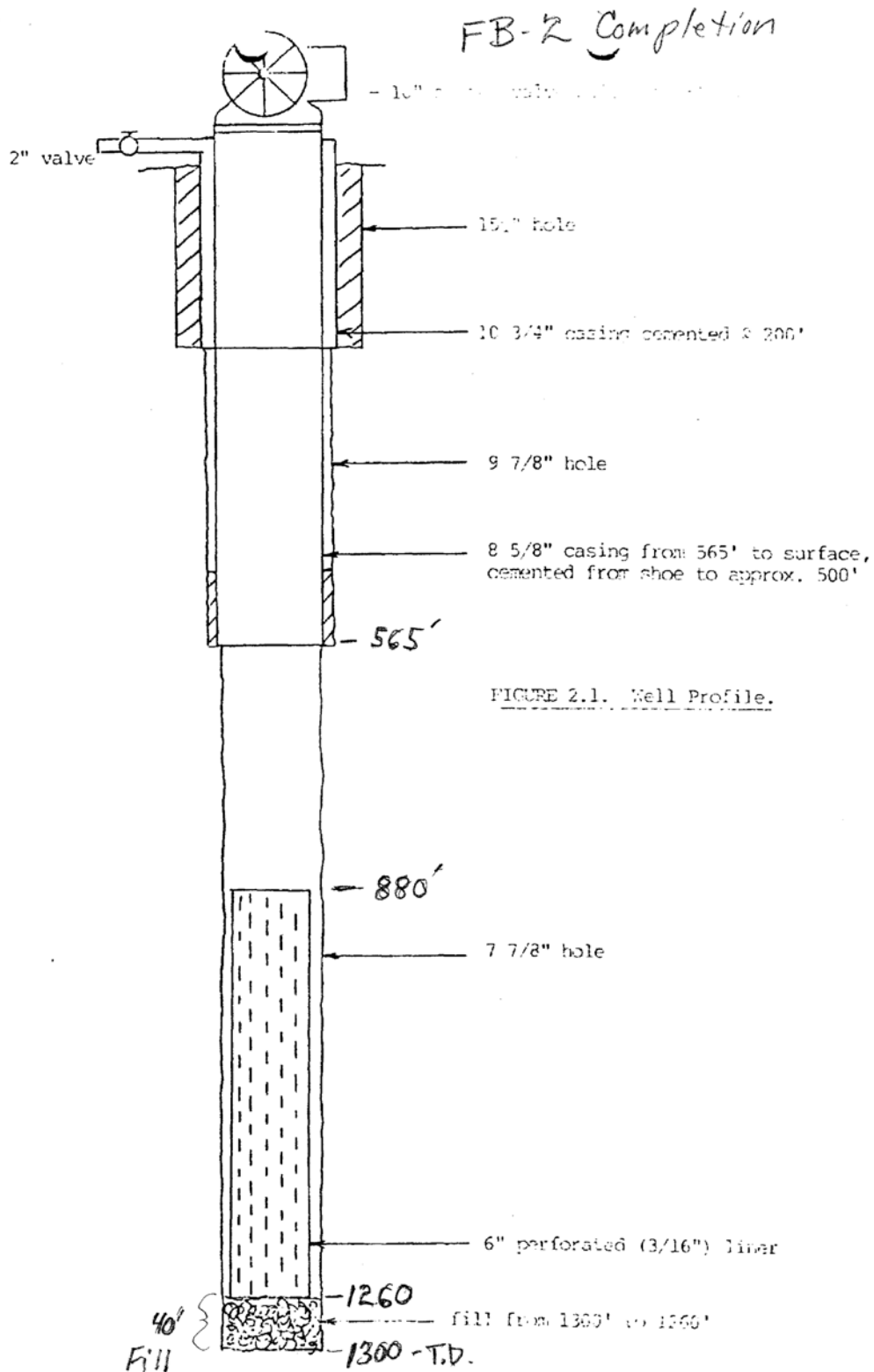


FIGURE 2.1. Well Profile.

PORT BIDWELL INDIAN COMMUNITY COUNCIL
 FB-2 (049-90014)
 17/46N/16E MD B&M

A-6. Well FB-1 Water Well Drillers Report (Atkinson 1981)

DUPLICATE
Driller's Copy

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not
No. 09924

Notice of Intent No. _____
Local Permit No. or Date _____

State Well No. _____
Other Well No. _____

(1) OWNER: Name Hydrothermal Energy Corp.
Address 210 Marsh Ave.
City Reno, Nevada Zip 89509

(2) LOCATION OF WELL (See instructions):
County Modoc Owner's Well Number # 1
Well address if different from above _____
Township _____ Range _____ Section _____
Distance from cities, roads, railroads, fences, etc. _____

On the Ft. Bidwell Indian Reservation

(3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic ☐
Irrigation ☐
Industrial ☒
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

WELL LOCATION SKETCH

(5) EQUIPMENT:
Rotary ☐ Reverse ☐
Cable ☐ Air ☒
Other ☐ Bucket ☐

(6) GRAVEL PACK:
Yes ☒ No ☐ Size 3/8 to 1/2 pea
Diameter of bore 12 1/4"
Packed from _____ to _____ ft.

(7) CASING INSTALLED:
Steel ☒ Plastic ☐ Concrete ☐

(8) PERFORATIONS:
Type of perforation or size of screen _____

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
11 1/2	140	12	3/4"	188	Blank	Cemented in
121.73	261	30	8 5/8"	188	Blank	
261.30	500.00	8 5/8"	x.188	Perf	1/8"x3	16 slots per ft.

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 140 ft.
Were struts sealed against pollution? Yes ☐ No ☒ Interval _____ ft.
Method of sealing Cement

(10) WATER LEVELS:
Depth of first water, if known _____ ft.
Standing level after well completion Artesian ft.

(11) WELL TESTS:
Was well test made? Yes ☒ No ☐ If yes, by whom? Driller
Type of test _____ Pump ☐ Bailer ☐ Air lift ☒
Depth to water at start of test _____ ft. At end of test _____ ft.
Discharge 450 approx gpm _____ hours Water temperature 116
Chemical analysis made? Yes ☐ No ☒ If yes, by whom? _____
Was electric log made? Yes ☒ No ☐ If yes, attach copy to this report

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Signed Thomas E. Walker (Well Driller)
NAME Walker Drilling & Pump Co Inc
Address Rt. 3, Box 107
City Sunnville, CA. Zip 96131
License No. 334033 Date of this report 10/1/81

D-168 (REV. 7-78) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Appendix B – Communications and Emergency Contingency Plans Document

This document contains the Communications and Emergency Contingency Plans for field activity to be carried out on the Well FB4, located within the Fort Bidwell reservation. The work is being carried out under Task 2.2 (Well Testing) of the above-reference Grant. The information in this document comprises Task 2.1 of the Grant Project.

Emergency Contingency Plan

Call 9-1-1 in case of emergency.

Local medical resources include:

A Nurse at the Warner Mtn. Medical Center on the reservation during normal business hours. 530-279-6195

A Nurse/Doctor at the Surprise Valley Community Hospital in Cedarville, about 25 miles south. Open 24 Hours. 530-279-6111

A Hospital at the Modoc Medical Center in Alturas 50 miles away. Open 24 Hours. 530-233-5131

Additional information about emergency medical and fire contacts is provided below.

There will be an onsite, pre-job safety meeting. This will include a job hazard review and requirements for personal protective equipment (PPE) for all personnel on the location. Below is a copy of the Job Hazard Review form to be used.

Standard PPE includes hard hat, gloves, safety glasses, steel toe shoes and personal H2S monitor. Personnel without the standard PPE may be limited to certain parts of the location as determined by the project engineer.

Project Communication Plan

Data resulting from the well survey will be provided to the Project Engineer, who will then transmit it to the FBIC Grant Manager and the Energy Commission Grant Project Manager.

Below is a listing of names and contact information for the FBIC Project, the Fort Bidwell Tribe, and the Energy Commission. Other local information is also provided.

EMERGENCY PHONE LIST

MEDICAL EMERGENCY

Emergency Dispatch	Modoc County Sheriff, Alturas (from landline phone) California Highway Patrol, Susanville (from cell phone)	911
Nurse	Warner Mtn. Medical Center On Reservation	530-279-6195 Open Business Hrs
Nurse/Doctor	Surprise Valley Community Hospital Cedarville – Call Ahead. About 25 mi. North of NE corner of main intersection.	530-279-6111 Open 24 Hours
Hospital	Modoc Medical Center Alturas. About 50 mi.	530-233-5131 Open 24 Hours

FIRE EMERGENCY

Emergency Dispatch	Fire	911
Town of Ft. Bidwell Volunteer Fire Department (Dean Anderberg, Acting Chief)		530-279-2045
Modoc National Forest, Alturas Forest Supervisor's Office Lands south and west of the reservation		530-233-5811
Bureau of Land Management, Cedarville Office Lands northeast and south of the reservation		530-279-6101 530-279-2734 (engine bay)

JOB HAZARD REVIEW FORM

Pacific Process Systems, Inc.

JOB HAZARD REVIEW FORM				TICKET #
Customer/Lease:		Job site:		
Customer Contact:		Phone:	Date:	
Job Scope:				
Customer Supervisor:		PPS Supervisor:		
Fires/Explosion	Dangerous Atmospheres/ Conditions/Chemicals	Personal Protective Gear	Permits/Documentation	
Fuel Source:	Hydrogen Sulfide(H ₂ S)	Hard Hats	MSDS	
Gas	Carbon Monoxide (CO)	Safety Glasses	Hot Work Permit	
Liquid	Carbon Dioxide(CO ₂)	Face Shields	Confined Space Permit	
Solid	Hydrocarbons(CH _x)	Chemical Goggles	Evacuation Plan	
Ignition Source:	Absence of Oxygen(O ₂)	Hearing Protection	Other Permit (Describe):	
Flame	Engulfment	Safety Toed Boots		
Electric	High Voltage(>600 volts)			
Spark	Low Voltage(<600 volts)			
Friction/Static	Steam	Gloves		
	Hot Water	Leather		
		Rubber/Chemical Resistant	Purge Plan	
Testing/Monitoring Equipment	Hot Oil/Gas	Thermal	Lifting Plan	
Calibrated	Acid (Low pH)	Voltage Rated	Energy Control (Lockout, Blinding, Tagging) Log Sheet	
Personal Monitor	Caustic (High pH)	Other Equipment		
Stationary/Pole Mounted	High Pressure (Oil, water, gas, Chemical)	Protective Clothing/Suits	Emergency Plan	
O ₂	Temperature >150°F	Insulating Blankets/Line Covers	Other (Describe):	
H ₂ S	Confined Space	Signs/Barricades		
LEL	Electrical Clearance	Fire Extinguishers		
Wind Sock	Climbing Space	Fire Hose		
Tools & Equipment	Overhead Obstructions/ Clearance	SCBA		
Proper Rating/Size		Fresh Air System		
Good Condition	Underground Piping, Electrical, Obstructions	Mechanical Ventilation		
		Electrical Clearance		
Outside Parties (Operators, etc)	Pole Condition	Bonding Leads		
Affected		Dry Ice		
Understand		Purge Gas		
		Other (Describe):		
Outline Job Steps or Tasks				
Employees' Signatures: _____				

Employee that filled out JSA: (Print Name) _____

FBIC PROJECT PHONE LIST

<u>Project Role</u>	<u>Contact</u>	<u>Cell Phone</u>	<u>Email</u>
Engineer	Paul Atkinson	530-919-2981	atkinsonconsulting@comcast.net

FBIC AND AGENCY CONTACTS

Tribal Council Chair: Bernold Pollard	Tribal Council Co-Chair: Jon MacErnie		
FBIC Grant Manager and Tribal Administrator	John Vass	530-640-2128	johnvass@citlink.net
FBIC Environ. Manager	Leslie Brooks	530-279-6310, ext. 1, then 2	brooksepo@live.com
CA Energy Commission Grant Project Manager	John Hingtgen	916-651-9106	Jhingtge@energy.state.ca.us

OTHER USEFUL CONTACTS

Sunrise Motel, Highway 299, Cedarville -- 530-279-2161

Surprise Valley Hot Springs, 530-279-2040 or toll free 877-927-6426

Appendix C – Fort Bidwell Fault Mapping

Figure C-1 presents the surface traces of Fort Bidwell area faults. These include the same faults presented previously (Figure 8 of LaFleur, 2005).

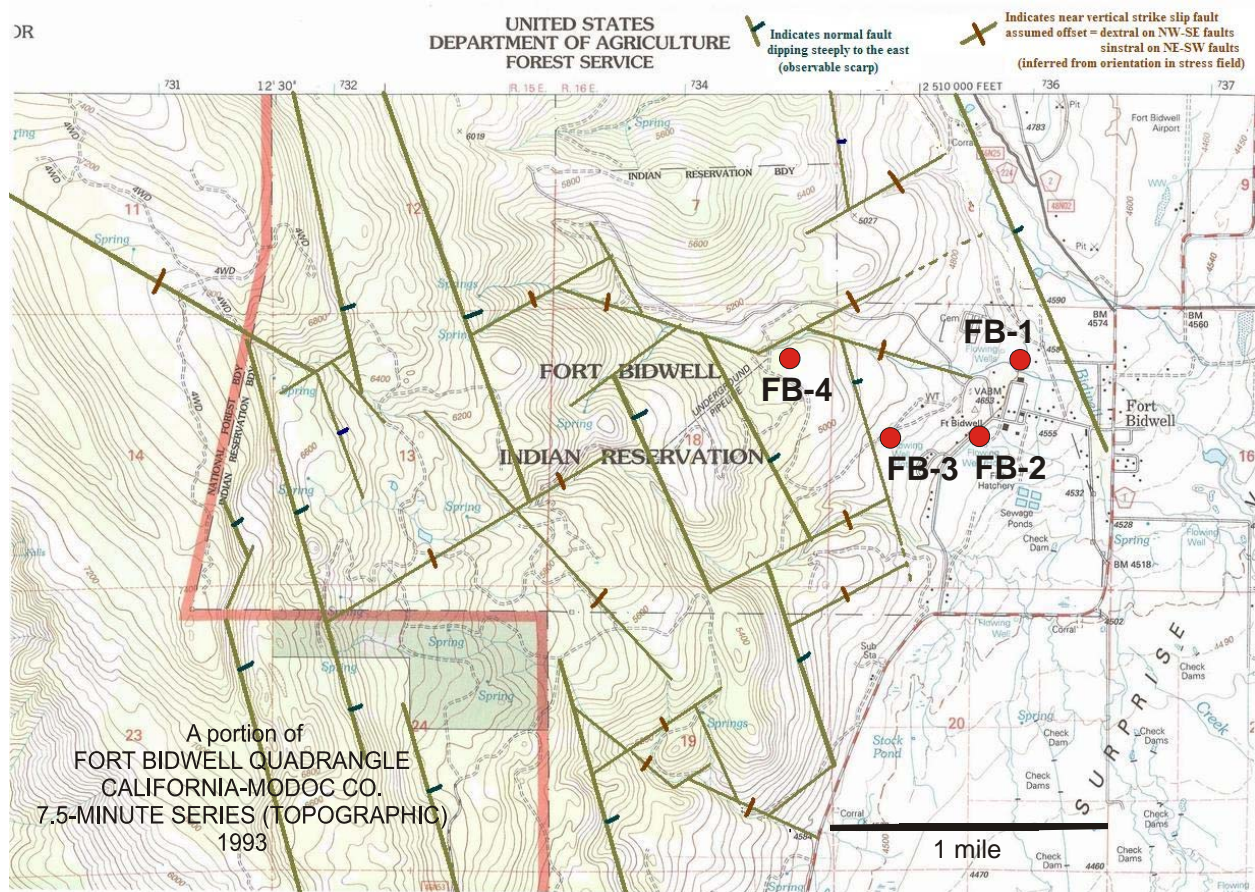


Figure C- 1 Surface Traces of Fort Bidwell Area Faults

The fault mapping was conducted as part of the previous study (Figure 8 of LaFleur, 2005) using satellite imagery, aerial photography, and field inspection. The satellite investigation was done using Google Earth, which provides good resolution imagery for this area. The aerial photography was specifically ordered for the purpose of mapping the faults. It was obtained from the USDA field office, Salt Lake City, and consisted of 1:40,000 scale, black & white, stereographic coverage. Several weeks were spent on the ground during the earlier study observing the fault scarps and walking out the drainages.

The remainder of this appendix provides some general comments about the Fort Bidwell area and its relationship to the larger region, and within which the surface manifestation of the fault interpretation was made.

Fort Bidwell is located in the western portion of the Basin and Range Province. The primary tectonic features of the area are the result of what is traditionally known as "Basin and Range extension". This tectonic process produces relatively uplifted "horst" blocks that form the mountain ranges, and relatively down-dropped "graben" valleys. The margins of the valleys are defined by the primary "range-front" faults, which are generally coincident with the abrupt change in slope. Typically, faulting sub-parallel to the range front can be observed within the uplifted block. This area is also significantly affected by the stress field generated by the interaction of the Eastern Pacific Plate and North American Plate.

Hydrothermal systems are often found coincident with the range front faulting. Geothermal exploration in the Basin and Range is finding more examples of hydrothermal upflow within the sub-parallel faulting that outcrops higher within the up-faulted block.

The town of Fort Bidwell is on the northwest margin of the Surprise Valley graben, and the Reservation extends westward up into the Warner Range horst block. The regional alignment of these mega-features is N-S; however, locally at Fort Bidwell, the range-front faulting has a NNW direction. The few hydrothermal features in the area occur along the range front.

Like the rest of California and the western Basin and Range, the tectonics at Fort Bidwell are also subject to the stress field generated by the regional plate motion of the Western US. The "drag" imparted to the western continental margin by the NW movement of the Western Pacific Plate, propagates eastward through California and into Nevada. The strain produced by tens of millions of years of this ongoing plate motion results in the formation of strike-slip type faulting or "shears". Unlike the Basin and Range faulting which demonstrates huge vertical offset, the strike-slip faulting generates conjugate shears that have predominantly horizontal offset. The primary shear direction is NW, parallel to the offshore plate motion, and has right-lateral offset. The ongoing ground motion produced by these shears is now being monitored by satellite throughout the Basin and Range as well as California. Large NW-trending shears abound in the western Basin and Range. Examples near Fort Bidwell would include Fandango Pass, 5 miles to the south, and upper Bidwell creek, a mile to the north of the Reservation. Often less recognized, are the NE-trending conjugate shears but they are observed to be prevalent when conducting more detailed local fault mapping.

Appendix D - Well Clean-Out Cost Estimate

Atkinson Consulting

Well: FB 4

Field: Fort Bidwell

Estimator: Hamblin

#	Daily Cost Category		\$/day	days/well	Sub total	T/I
46	Rig move day rate	Mob & demot	10,000	6	60,000	I
46	Trucks and cranes for rig move	Mob & demot	160,000	1	160,000	I
49	Rig stand-by rate			0	0	I
49	Rig operating day rate		14,000	6	84,000	I
50	Air compressor equipment standby		900	2	1,800	I
50	Air compressor service hands + equipment operating rate		1,900	2	3,800	I
51	Supervision:		1,600	10	16,000	I
52	Stabilizers, Reamers and Hole Opener		2,000	3	6,000	I
54	Casing crews and lay down machin		8,000	1	8,000	I
56	Downhole tools: jars, shock subs, etc		500	6	3,000	I
57	Mud Logging/H ₂ S Services:		1,950	3	5,850	I
57	H ₂ S Chemicals				0	I
58	BOP Rental		2,500	6	15,000	I
58	Top Drive Rental				0	I
62	Welding		1,000	8	8,000	I
64	Fishing Tools and Service				0	I
66	Forklift and Backhoe Renta		400	6	2,400	I
66	DP, HWDP and DC's rental		0	0	0	I
67	Solids control equipment and mud cooler		0	0	0	I
69	Transportation		2,500	10	25,000	I
72	Fuel, Water and Power		2,250	6	13,500	I
73	Communications		0	0	0	I
73	Pason		400	6	2,400	I
77	Perforating				0	I
79	Camp Costs		750	6	4,500	I
						I
						I
Total Daily Costs:					419,250	

#	Materials and Equipment Costs	Size/Item	Units	Avg. \$/unit	Sub total	T/I
52	Bits	26			0	I
52		17 1/2			0	I
52		12 1/4			0	I
52		8 1/2	1	10000	10,000	I
52		8 3/4	0	0	0	I
21	Casing (units = feet)	28	80		0	T
21	Casing	20	500		0	T
21	Casing	13 3/8	1,500		0	T
21	Casing	9 5/8	4,500		0	T
21	Casing	9 5/8	3,500		0	T
22	Tubing	7	2,800	25	70,000	T
22	Drill Pipe purchases:				0	T
23	Production Valves	16			0	T
23	Wing Valves	3			0	T
23	Casing head(s)				0	T
23	Spools, studs, nuts, misc well hea				0	T
66	Drilling Tools Rebuild/Repair	Hardbanding			0	I
66		DP repair	1	5000	5,000	I
66		Subs repair	1	1000	1,000	I
66		Other tools			0	I
58	Well Control Equipment	BOP Rubbers			0	I
58		Rot. Head Rbrs			0	I
58		Floats:			0	I
25	Casing Accesorie:	Liner Hanger			0	T
25		Liner adapters	3,000	1	3,000	T
25		Centrallizers			0	T
25		Bridge Plugs			0	I
25		Misc. Supplies			0	T
45	Permits, Surveying, Conductor, Site				0	I
53	Mud material costs				10,000	I
55	Cement material and job costs (see cement estimation worksheet)				0	I
59	Testing, Sampling and Coring				0	I
61	Wireline surveys/log:				0	I
63	Directional drilling equipment and operators charges (see directional workshee				0	I
68	Small Tools and Misc. Supplies:				0	I
74	Well Insurance				0	I
78	Completion Cost:				0	I
84	Miscellaneous Expense:				0	I
85	Abandonment Cost:				0	I
Total Materials and Equipment					99,000	

T = Tangible, I = Intangible

	Tangible	73,000
	Intangible	445,250
10%	Contingency	44,525
	Grand Total	562,775